AD-A284 093

DOT/FAA/RD-93/31,II

Research and Development Service
Washington, DC 20591

Rotorwash Analysis Handbook

Volume II - Appendixes

Samuel W. Ferguson
EMA
800 Muirfield Drive
Mansfield, TX 76063

June 1994

Final Report

This document is available to the public through the National Technical Information Service, Springfield, VA 22161

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/RD-93-31, II	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Rotorwash Analysis Handbook, Volume II: Appendixes		5. Report Date June 1994 6. Performing Organization No.
7. Author (s) Samuel W. Ferguson, EMA		8. Performing Organization Report No. SCT No. 93RR-17
9. Performing Organization Name and Address Systems Control Technology, Inc. 1611 North Kent Street, Suite 910 Arlington, VA 22209		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFA01-87-C-00014
12. Sponsoring Agency Name and Address Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591		13. Type Report and Period Covered Final Report 14. Sponsoring Agency Code ARD-30

15. Supplementary Notes

1. Work was performed under Subcontract T-2608-002 by EMA, Mansfield, TX
2. ARD-30 Vertical Flight Program Office

16. Abstract

Documentation, a program listing, and a user's guide are provided for version 2.1 of the FORTRAN 77-based ROTWASH computer program in report appendices. An extensive bibliography of rotorwash related technical documents is also provided. This listing is subdivided into different rotorwash topics.

A companion report, entitled "Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight," DOT/FAA/RD-90/16, evaluates rotorwash characteristics of 11 different types of tiltrotor and tiltwing aircraft for comparison purposes. Another companion report, entitled "Analysis of Rotorwash Effects in Helicopter Mishaps," DOT/FAA/RD-90/17, presents an analysis of several of the more common types of rotorwash related helicopter mishaps. Much of the information provided in this second companion report is updated by this report. A third report, DOT/FAA/RD-90/25, "Rotorwash Computer Model - User's Guide," is replaced by this more comprehensive report and its updated version of the ROTWASH computer program.

17. Key Words Heliports Airport Planning Heliport Design Downwash Rotorcraft Ground Effects (Aerodynamics) Rotor Downwash Helicopters	18. Distribution Statement This document is available to the U.S. Public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 193	22. Price

TABLE OF CONTENTS - VOLUME I

Page

Page

TABLE OF CONTENTS - VOLUME II

LIST OF FIGURES

Page

Page

Page

Page

Page

Page

LIST OF TABLES

APPENDIX A
ROTORCRAFT DESIGN DATA IN ROTWASH FORMAT

TABLE A-1 ROTORCRAFT DATA SUMMARY

Rotorcraft Manufacturer/ Type	Maximum Gross Weight (lb)	Main Rotor Radius (ft)	Estimated Fuselage Download (Pct)	Rotor Disk Loading (psf)	Number of Rotors/Blades per Rotor	Rotor Tip Speed (fps)	Rotor Height Above Ground (ft)	Twin Rotor Separation (ft)
Aerospatiale								
SA341G	3,970	17.25	1.5	4.24	1/3	683	8.9	--
SA342L	4,410	17.25	1.5	4.73	1/3	698	8.9	--
AS350B	4,299	17.55	2.0	4.44	1/3	698	10.3	--
AS550	4,960	17.55	2.0	5.12	1/3	698	10.3	--
AS555	5,600	17.55	2.0	5.79	1/3	698	10.3	--
AS355	5,291	17.55	2.0	5.47	1/3		10.7	--
SA315B	5,070	18.05	1.5	4.95	1/3		10.1	--
SA319B	4,960	18.05	1.5	4.84	1/3		9.8	--
SA360	6,615	18.85	2.0	5.92	1/4	690	11.5	--
SA365N	8,900	19.55	2.0	7.41	1/4	715	11.4	--
AS565	9,370	19.58	2.0	7.78	1/4	717	11.4	--
SA330	16,315	24.75	5.0	8.48	1/4	687	14.4	--
AS532 MK.I	19,840	25.60	5.0	9.64	1/4	711	15.0	--
AS532 MK.II	20,944	26.58	5.0	9.43	1/4		16.3	--
SA321	28,660	31.00	5.0	9.49	1/6	688	16.3	--
Agusta								
A109A	5,732	18.05	1.5	5.60	1/4	727	10.0	--
A109C	5,996	18.05	1.5	5.86	1/4	727	10.0	--
A129	9,039	19.52	2.0	6.80	1/4		10.5	--

TABLE A-1 ROTORCRAFT DATA SUMMARY (Continued)

Rotorcraft Manufacturer/ Type	Maximum Gross Weight (lb)	Main Rotor Radius (ft)	Estimated Fuselage Download (Pct)	Rotor Disk Loading (psf)	Number of Rotors/Blades per Rotor	Rotor Tip Speed (fps)	Rotor Height Above Ground (ft)	Twin Rotor Separation (ft)
Bell								
47	2,850	18.50	1.0	2.65	1/2	645-716	9.5	--
206	3,200	16.65	1.5	3.67	1/2	688	9.5	--
OH-58A	3,200	17.65	1.5	3.26	1/2	654	9.5	--
OH-58D	5,500	17.5	1.5	5.72	1/4	724	8.5	--
206L	4,150	18.5	1.5	3.86	1/2	763	10.1	--
222B	8,250	21.0	4.0	5.95	1/2	765	10.8	--
230	8,250	21.0	4.0	5.95	1/2	765	12.0	--
204	8,500	22.0	2.0	5.59	1/2	746	11.8	--
UH-1M	9,500	22.0	2.0	6.25	1/2	746	11.8	--
205	9,500	24.0	2.0	5.25	1/2	814	11.8	--
212	11,200	24.0	2.0	6.19	1/2	814	13.4	--
412	11,900	23.0	2.0	7.16	1/4	780	11.0	--
214B	13,800	25.0	2.0	7.03	1/2	785	14.0	--
214ST	17,500	26.0	2.0	8.[illegible]	1/2	781	14.2	--
AH-1S	10,000	22.0	2.0	6.58	1/2	746	12.3	--
AH-1T/W	14,750	24.0	2.0	8.15	1/2	781	13.5	--
XV-15	13,200	12.5	13.0	13.44	2/3	771	12.5	32.2
Bell/Boeing								
V-22	47,500	19.0	10.0	17.63	2/3	790	20.1	46.5

TABLE A-1 ROTORCRAFT DATA SUMMARY (Continued)

Rotorcraft Manufacturer/ Type	Maximum Gross Weight (lb)	Main Rotor Radius (ft)	Estimated Fuselage Download (Pct)	Rotor Disk Loading (psf)	Number of Rotors/Blades per Rotor	Rotor Tip Speed (fps)	Rotor Height Above Ground (ft)	Twin Rotor Separation (ft)
Boeing/Vertol								
CH-46E	24,300	25.5	7.0	5.95	2/3	705	16.6	33.3
CH-47C	46,000	30.0	8.0	8.13	2/3	723	18.6	39.2
CH-47D	54,000	30.0	8.0	9.55	2/3	707	18.6	39.2
Enstrom								
F28F/28C	2,600	16.0	1.5	3.23	1/3		9.1	--
Kaman								
SH-2	12,800	22.0	2.0	8.42	1/4	687	13.6	--
MBB								
BO105CB	5,512	16.11	1.5	6.81	1/4	715	9.7	--
BO108	5,511	16.4	1.5	6.52	1/4		9.8	--
BK117	7,055	18.05	2.0	6.90	1.4	725	11.0	--
McDonnell Douglas								
300	2,050	13.4	1.0	3.63	1/3	662	8.8	--
500D	3,000	13.2	1.5	5.48	1/4	665	8.5	--
500E	3,000	13.2	1.5	5.48	1/5	680	8.7	--
530F	3,100	13.7	1.5	5.28	1/5	684	8.7	--
AH-64	14,694	24.0	2.0	8.12	1/4	726	12.6	--
520N	3,350	13.67	1.5	5.71	1/5	684	8.7	--

TABLE A-1 ROTORCRAFT DATA SUMMARY (Continued)

Rotorcraft Manufacturer/ Type	Maximum Gross Weight (lb)	Main Rotor Radius (ft)	Estimated Fuselage Download (Pct)	Rotor Disk Loading (psf)	Number of Rotors/Blades per Rotor	Rotor Tip Speed (fps)	Rotor Height Above Ground (ft)	Twin Rotor Separation (ft)
Robinson								
R22	1,370	12.6	1.0	2.75	1/2	699	8.8	--
R44	2,400	16.5	1.0	2.81	1/2		10.5	--
Rogerson/Hiller								
UH-12	2,800	17.7	1.0	2.84	1/2		10.1	--
FH-1100	2,850	17.7	1.5	2.91	1/2		9.5	--
Schweizer								
300C	2,050	13.4	1.0	3.63	1/3	662	8.8	--
330	2,050	13.4	1.5	3.63	1/3	662	9.2	--
Sikorsky								
S-62	7,900	26.5	5.0	3.58	1/3			--
S-76	10,300	22.0	3.0	6.77	1/4	675	10.0	--
S-76B/C	11,700	22.0	3.0	7.69	1/4	675	10.0	--
UH-60A	20,250	26.85	3.0	8.94	1/4	725	12.3	--
UH-60L	22,000	26.85	3.0	9.71	1/4	725	12.3	--
S-61	20,500	31.0	5.0	6.79	1/5		17.0	--
SH-3	20,500	31.0	5.0	6.79	1/5	660	15.5	--
CH-3E	22,500	31.0	5.0	7.45	1/5		16.2	--
CH-54A	42,000	36.1	5.0	10.23	1/6		18.6	--
S-64E	42,000	36.1	5.0	10.23	1/6		18.6	--
CH-54B	47,000	36.1	5.0	11.54	1/6	700	17.6	--

TABLE A-1 ROTORCRAFT DATA SUMMARY (Continued)

Rotorcraft Manufacturer/ Type	Maximum Gross Weight (lb)	Main Rotor Radius (ft)	Estimated Fuselage Download (Pct)	Rotor Disk Loading (psf)	Number of Rotors/Blades per Rotor	Rotor Tip Speed (fps)	Rotor Height Above Ground (ft)	Twin Rotor Separation (ft)
Sikorsky (Continued)								
CH-53D	36,400	36.1	5.0	8.89	1/6	700	17.0	--
HH-53	38,275	36.1	5.0	9.35	1/6		17.0	--
RH-53D	41,126	36.1	5.0	10.04	1/6		17.0	--
CH-53E	70,000	39.5	5.0	14.28	1/7	733	17.0	--
Westland								
Lynx	10,500	21.0	2.0	7.58	1/4		9.8	--
Lynx(3)	12,000	21.0	2.0	8.66	1/4		10.0	--
W-30-200	12,800	21.8	2.0	8.57	1/4	745	12.5	--
W-30-300	15,500	21.8	2.0	10.38	1/4			--
EH-101	31,500	30.5	5.0	10.78	1/5		21.3	--
SEA KING	21,500	31.0	5.0	7.12	1/5	660	15.5	--
MIL (Soviet)								
MI-6	26,455	34.93	5.0	6.90	1/5		16.0	--
MI-14	30,865	34.93	5.0	8.05	1/5		22.0	--
MI-17	28,660	34.93	5.0	7.48	1/5		15.5	--
MI-26	123,450	52.50	5.0	14.26	1/8	725	26.0	--
MI-34	2,976	16.41	2.0	3.52	1/4			--

APPENDIX B
SIKORSKY CH-53E HELICOPTER AND ROTORWASH DATA

Sikorsky CH-53E helicopter characteristics used with the ROTWASH analysis program are listed in table B-1 as obtained from reference B-1. Figure B-1 presents a three-view drawing of the helicopter. Table B-2 provides a summary tabulation of parameters defining the conditions for all rotorwash data presented in this appendix. Flight test data used in correlation with the ROTWASH calculated data are obtained from reference 2 and were measured along the 270-degree azimuth (out the left side of the helicopter). Distance from rotor center (DFRC), gross weight (GW), and rotor height above ground level (RHAGL) are the primary independent variables for these measured data. Discussion of results is presented in section 3.1 of this report.

REFERENCES

B-1. Prouty, R.W., Helicopter Performance, Stability, and Control, Robert E. Krieger Publishing Company, Malabar, FL 32950, 1990.

B-2. Harris, D.J., and R.D. Simpson, "CH-53E Helicopter Downwash Evaluation," Naval Air Test Center Technical Report No. SY-89R-78, August 1, 1978.

TABLE B-1 CH-53E ROTWASH INPUT DATA

Parameter	Value
Rotor radius, feet	39.5
Distance between rotor centers, feet	0.0
Airframe download, percent of rotor thrust	5.0
Distance from wheels to rotor plane, feet	17.0
Rotor speed, RPM	177.0
Rotor tip speed, feet/second	732.0
Number of rotor blades per rotor	7
Density ratio	1.0

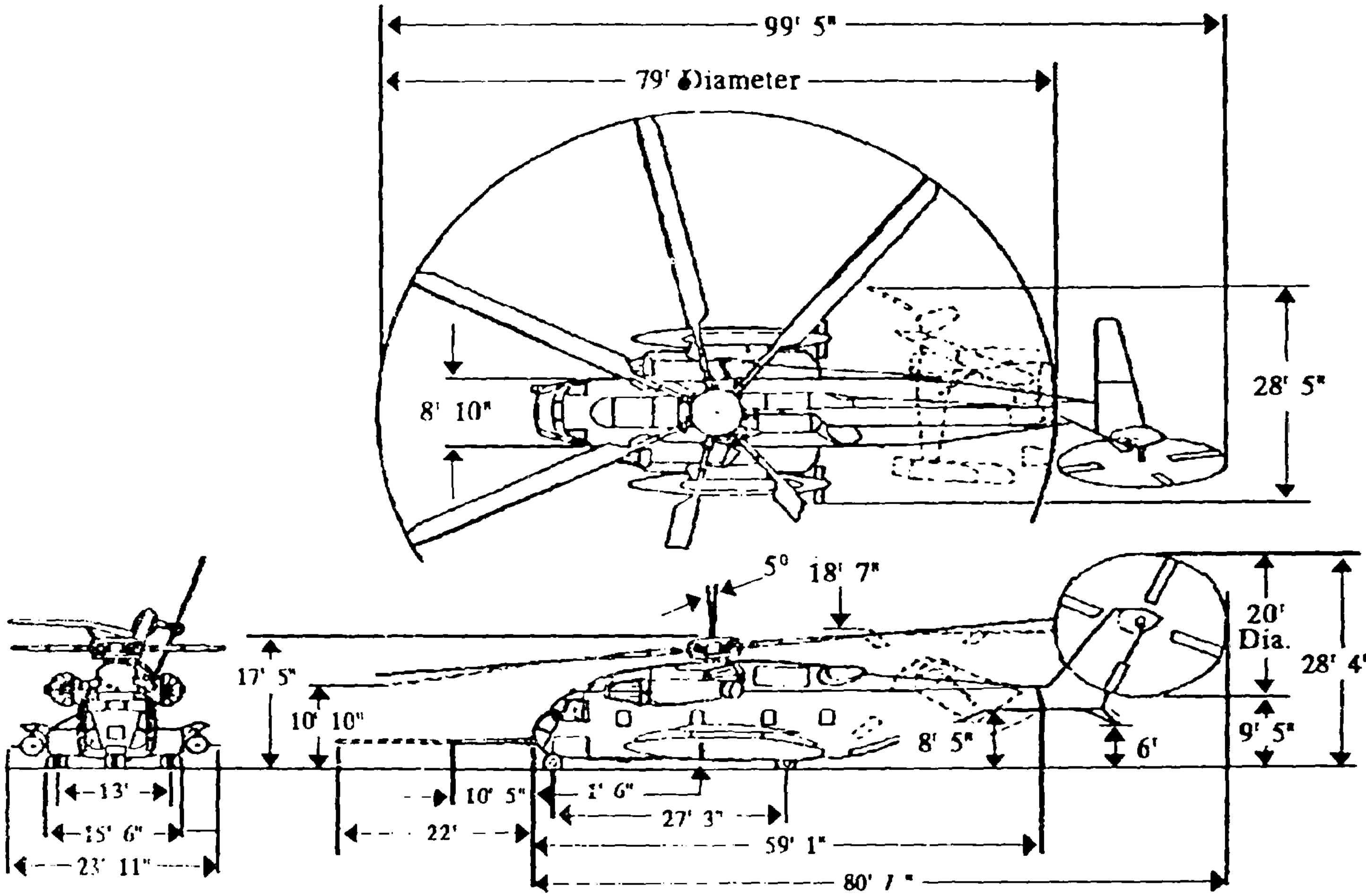


FIGURE B-1   THREE-VIEW DRAWING OF THE SIKORSKY CH-53E

TABLE B-2 EVALUATION MATRIX FOR CH-53E FLIGHT TEST MATHEMATICAL MODEL DATA CORRELATION

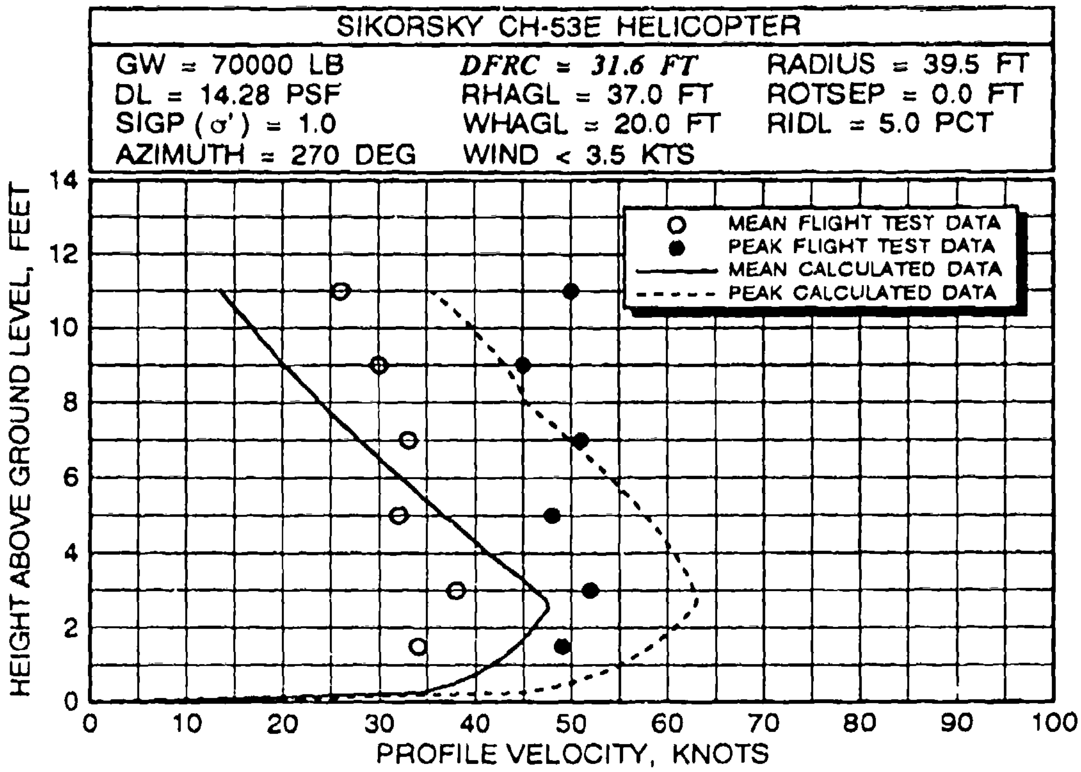
FIGURE NUMBER	GROSS WEIGHT (lb)	DISK LOADING (lbs/ft^2)	ROTOR HEIGHT (feet)	DISTANCE FROM ROTOR CENTER (DFRC) (feet)
B-2	70,000	14.28	37.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-3	70,000	14.28	77.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.9
B-4	70,000	14.28	117.0	31[illegible], 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-5	56,000	11.42	37.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-6	56,000	11.42	77.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-7	56,000	11.42	117.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-8	45,000	9.18	37.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-9	45,000	9.18	77.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8
B-10	45,000	9.18	117.0	31.6, 39.5, 49.4, 59.3, 69.1, 79.0, 118.5, 177.8

NOTES:

1) The values of DFRC are only applicable along the 270-degree azimuth.

2) Ambient winds varied between 0 and 3.5 knots.

3) Atmospheric density ratio was assumed equal to 1.0 since pressure altitude (which was near sea level) was not documented in reference B-2. Ambient temperature was measured from 39 to 45 degrees Fahrenheit during testing.



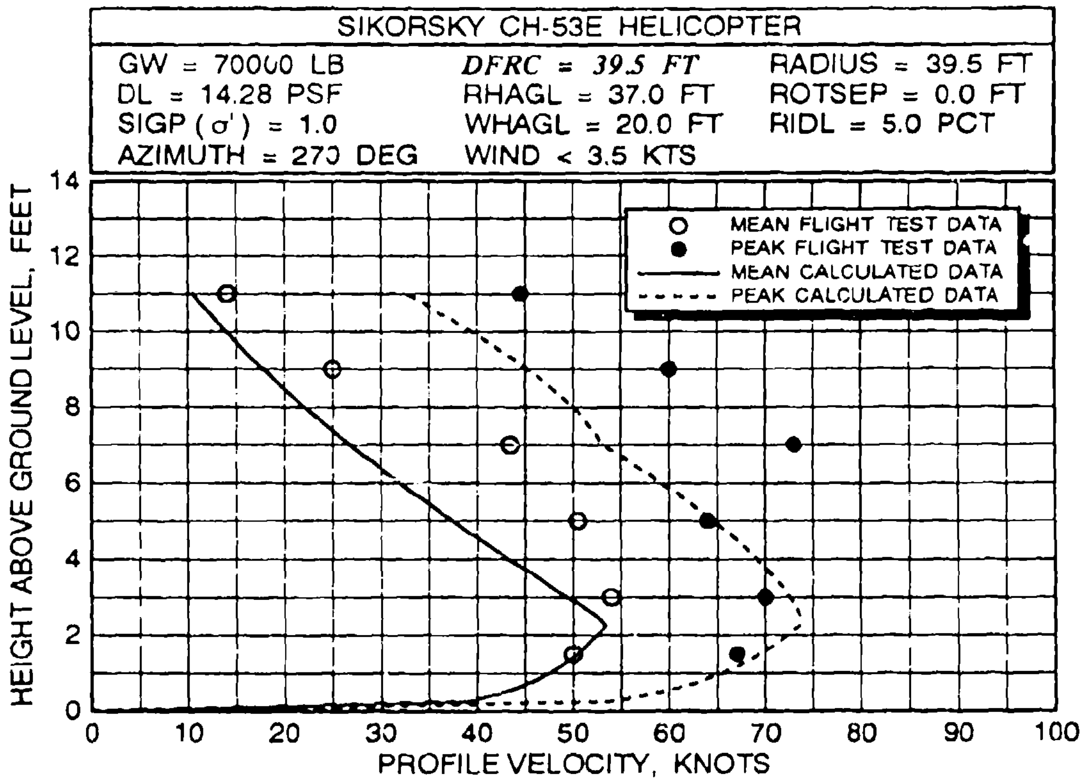
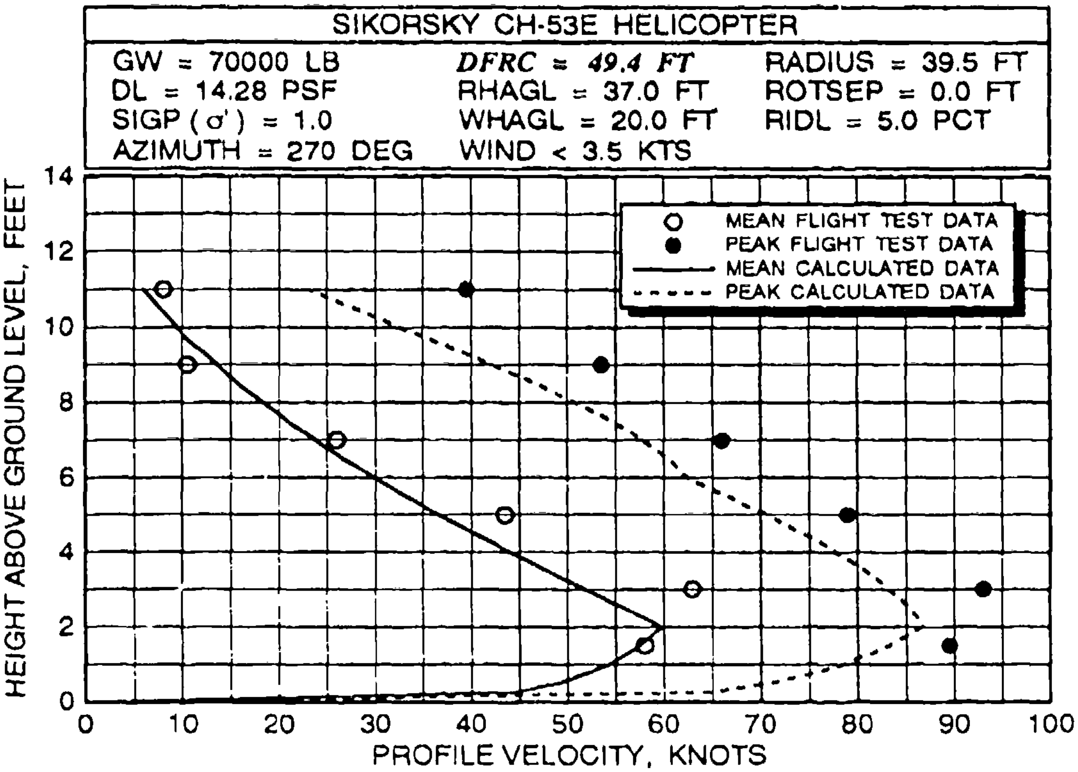


FIGURE B-2 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 70,000 POUNDS



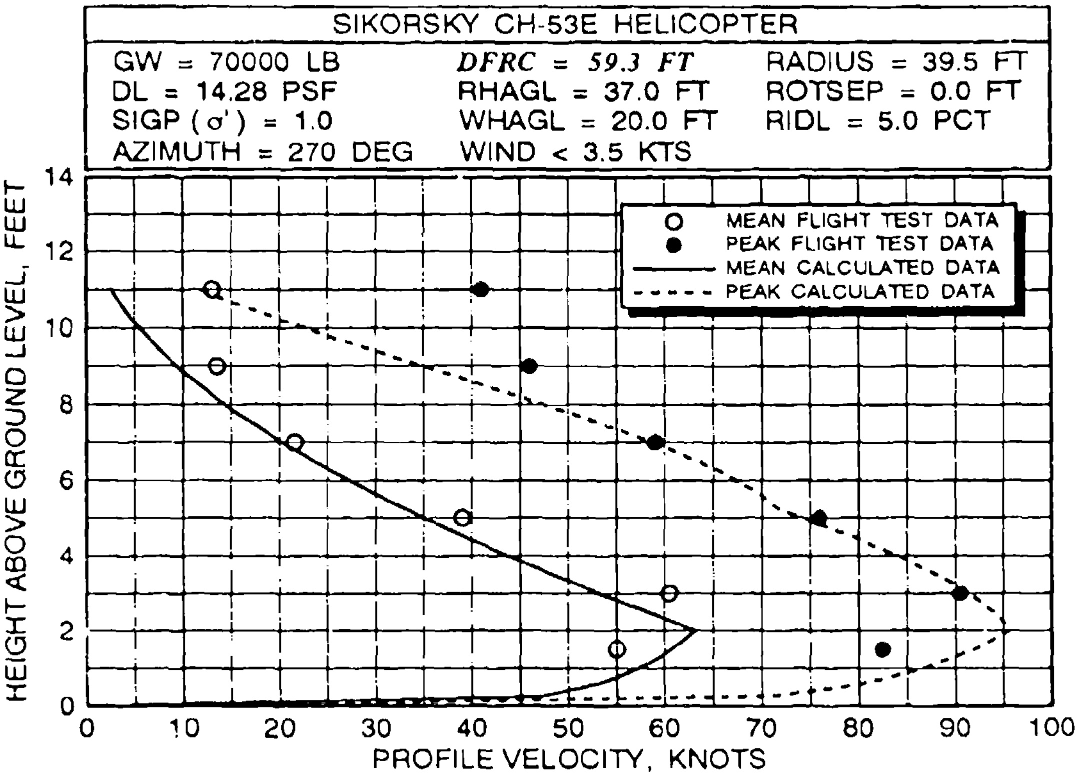
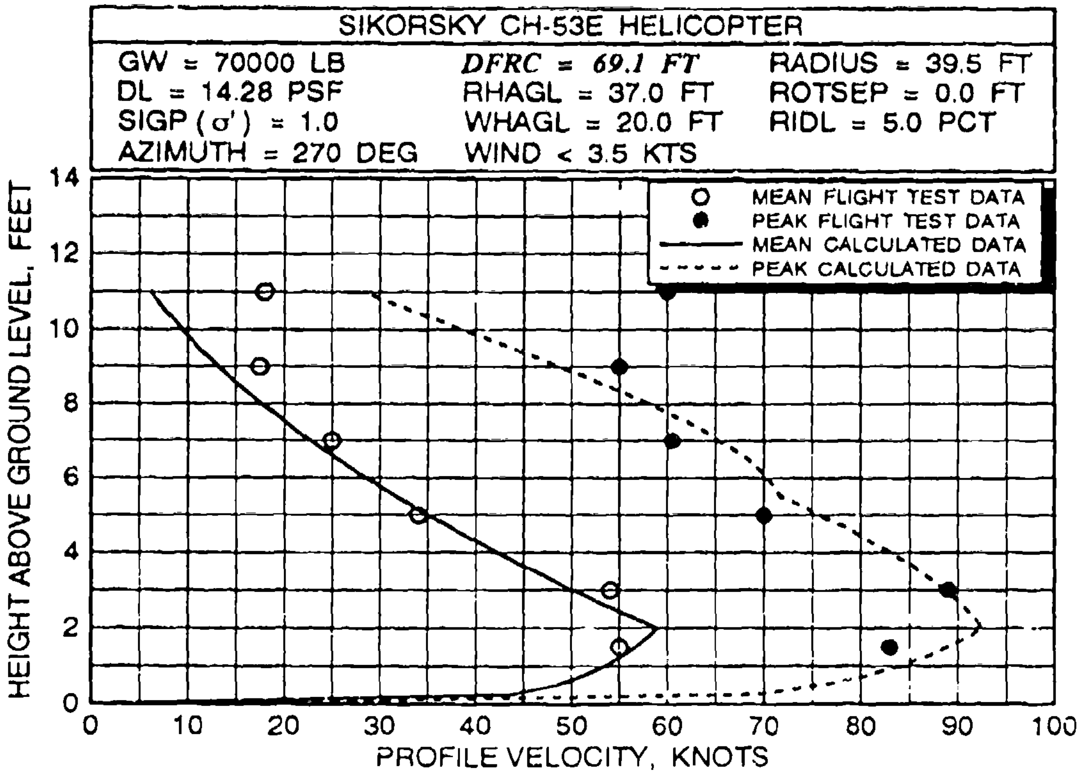


FIGURE B-2 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



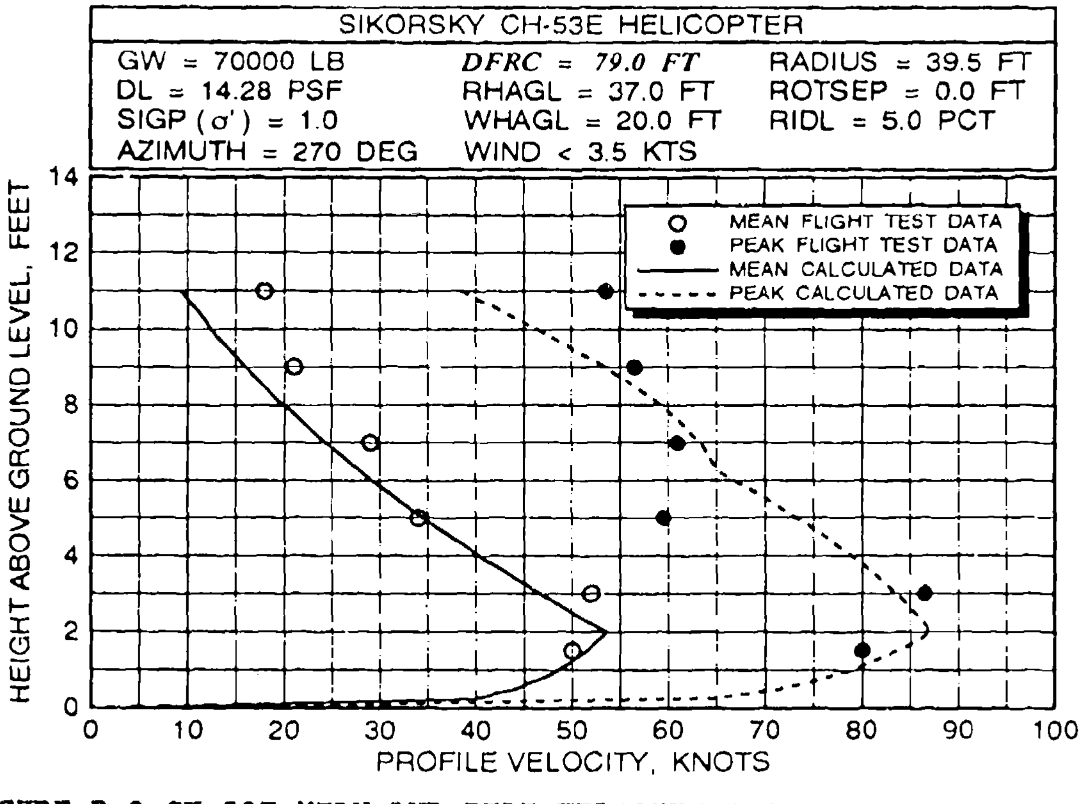
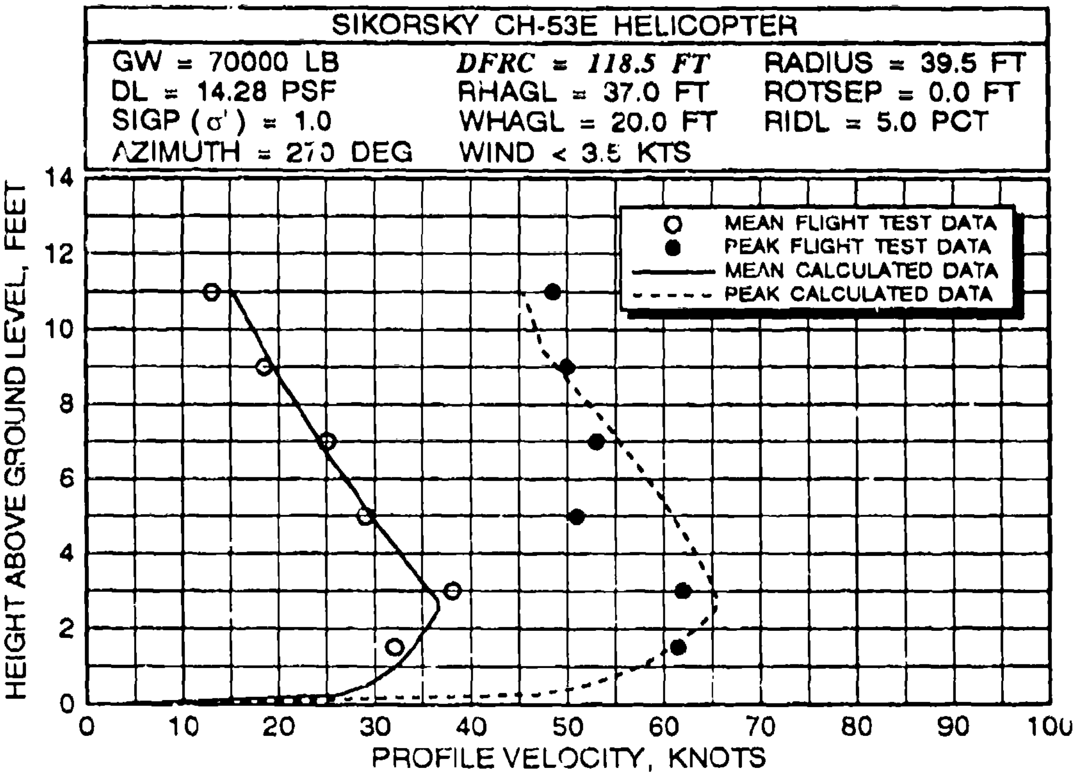


FIGURE B-2 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



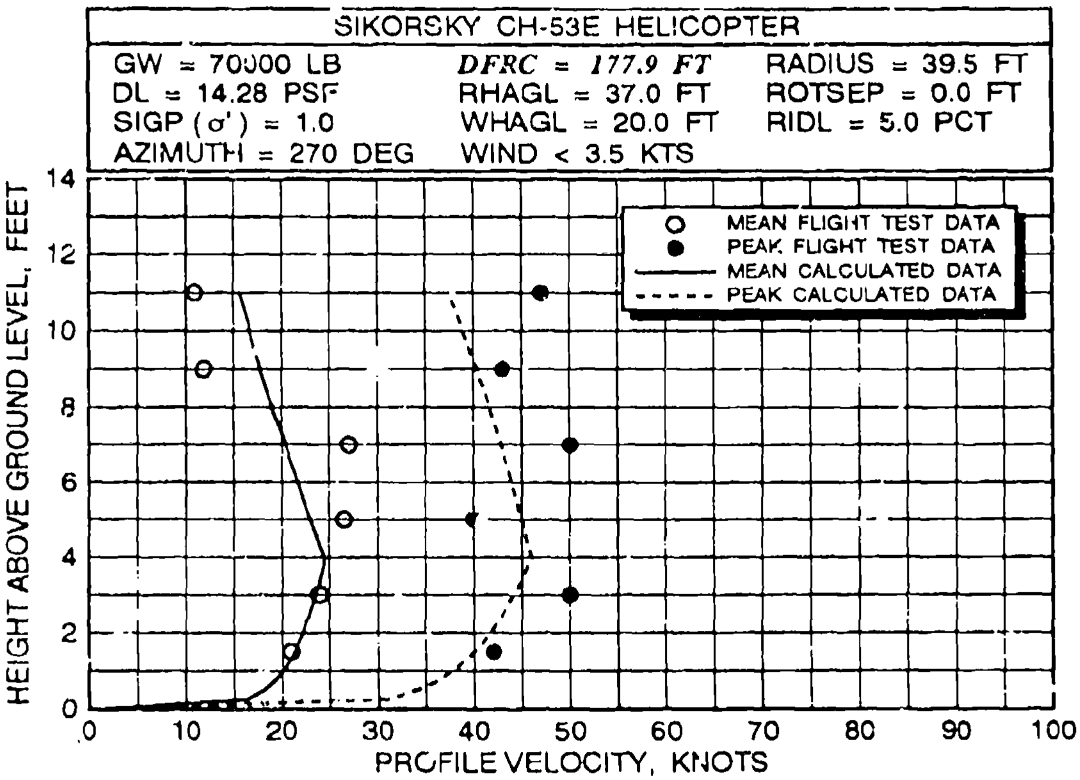
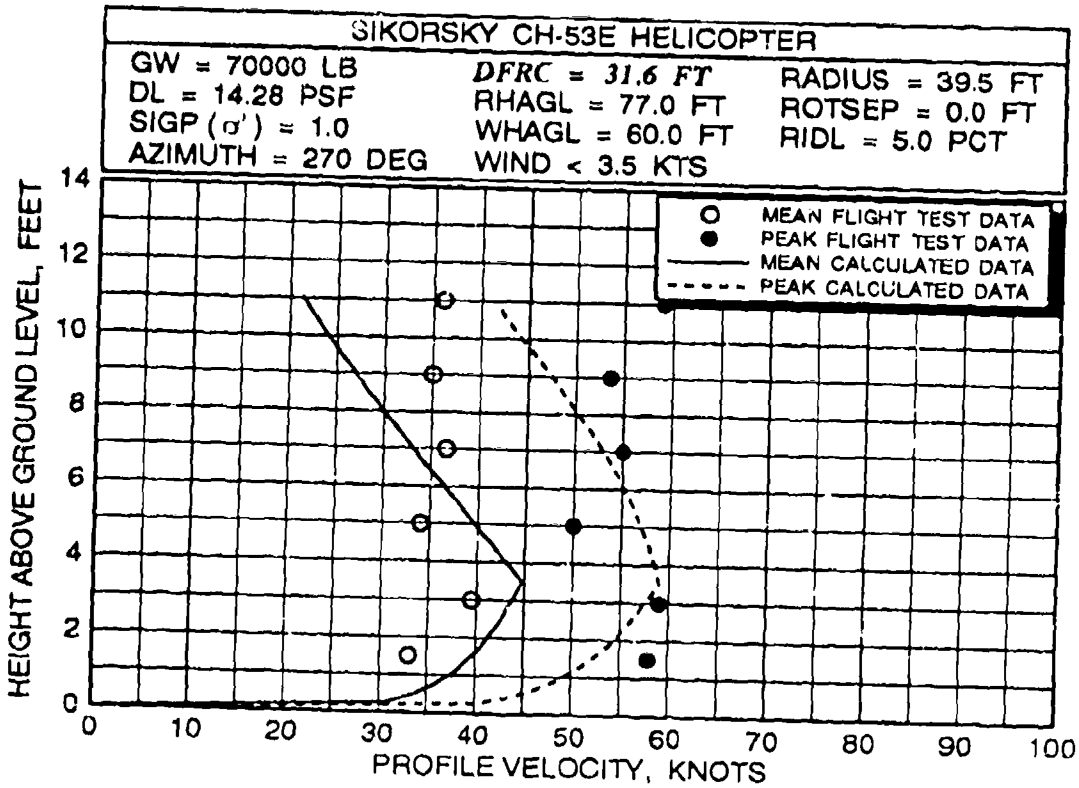


FIGURE B-2 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



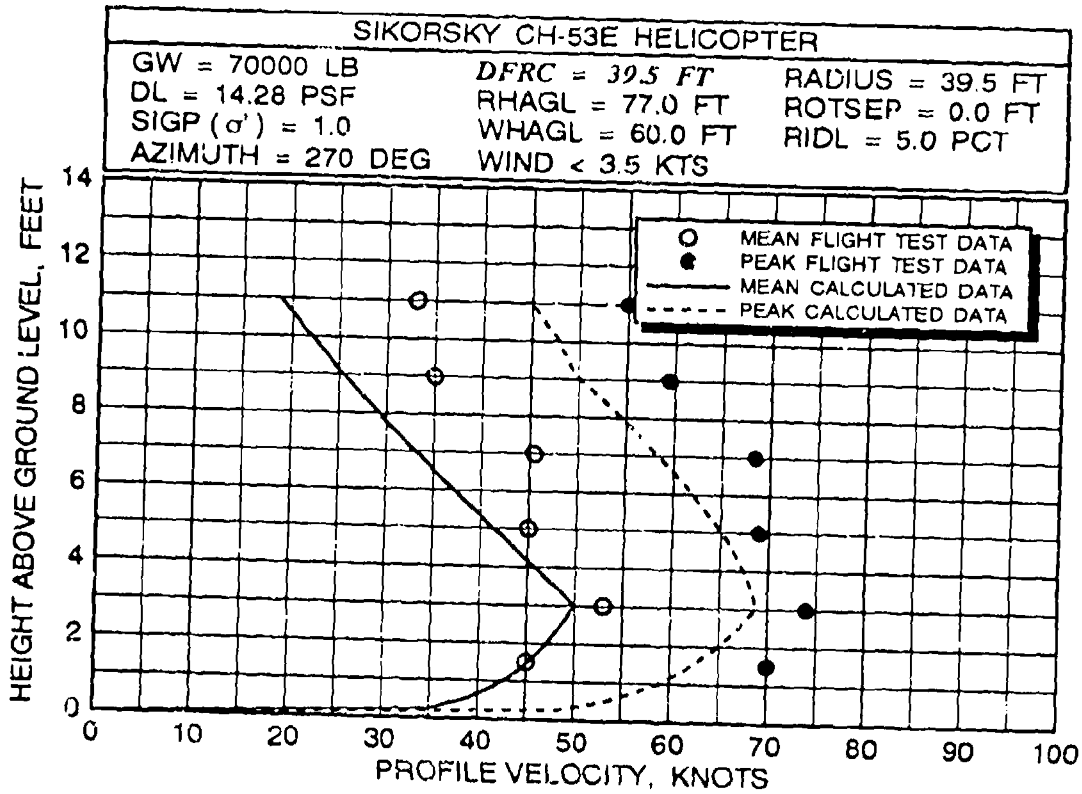
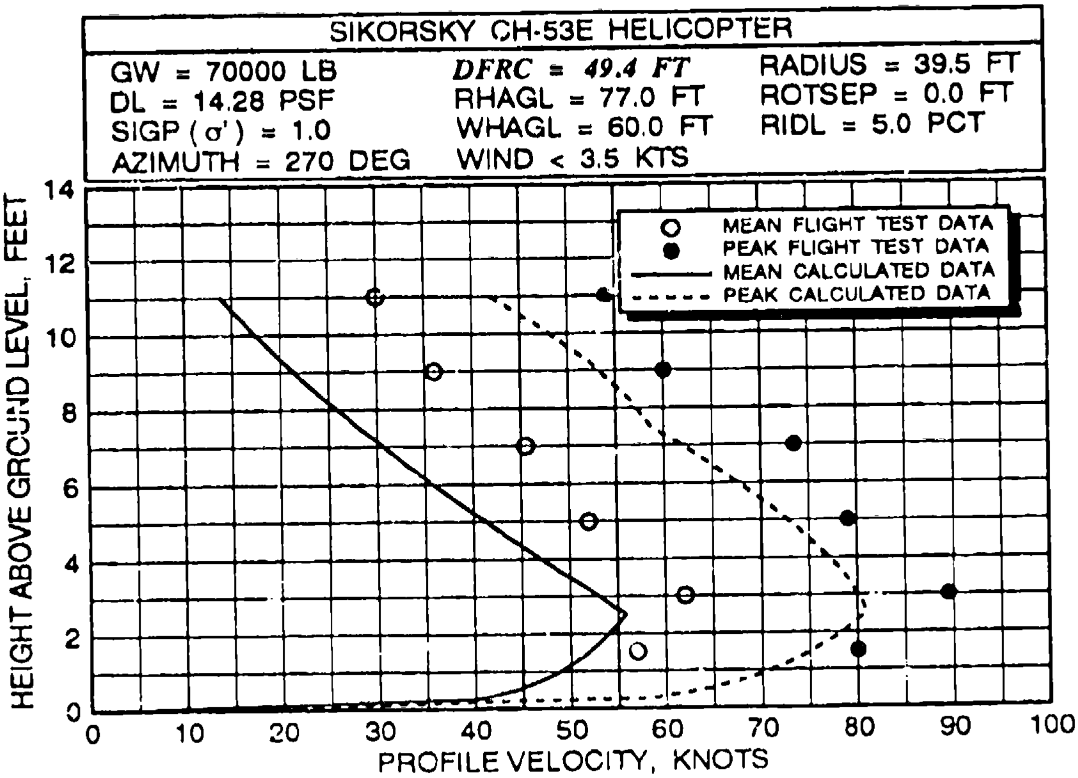


FIGURE B-3 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 70,000 POUNDS



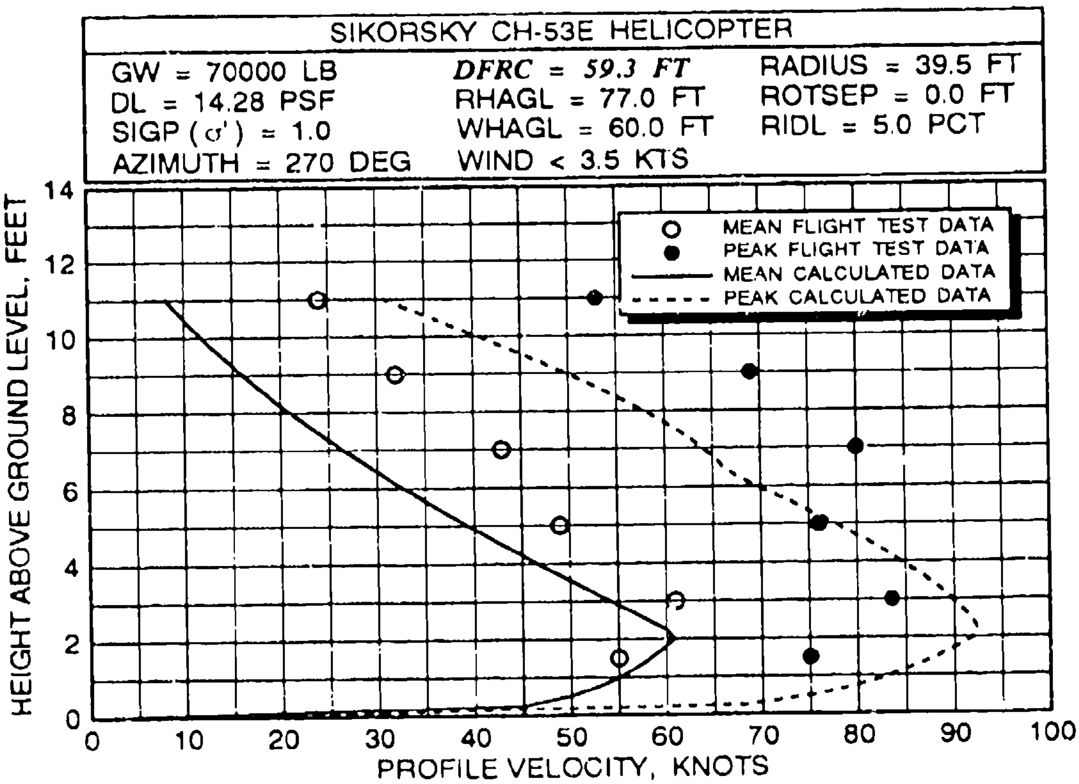
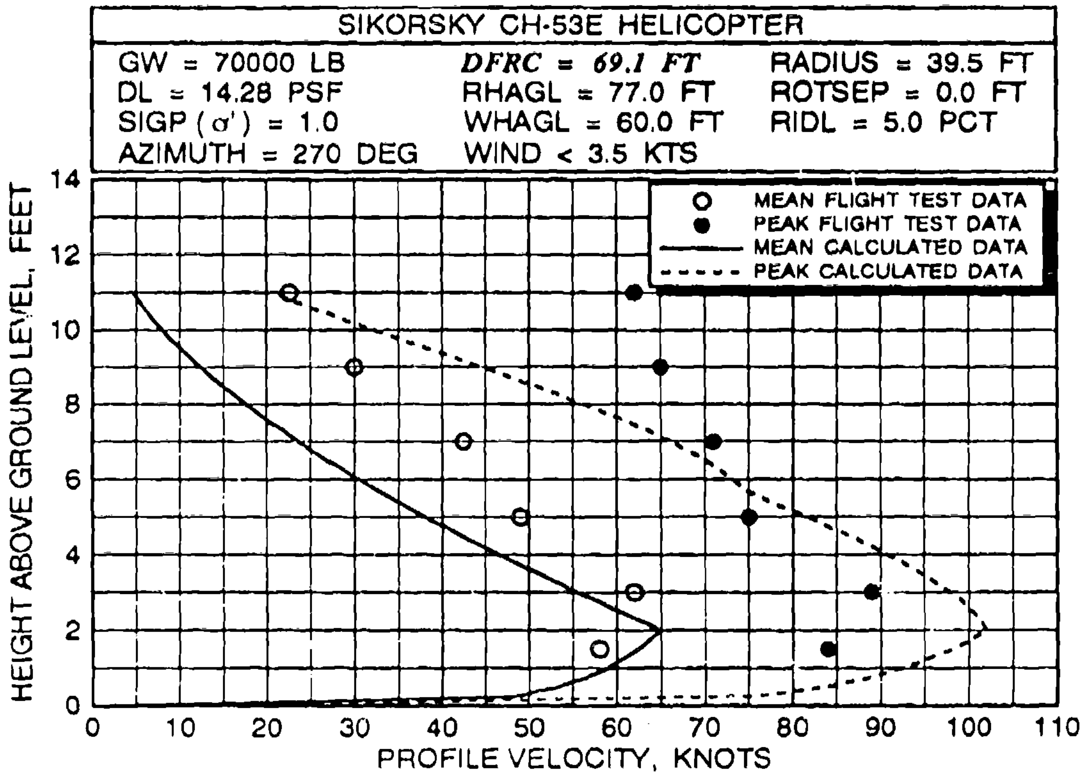


FIGURE B-3 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



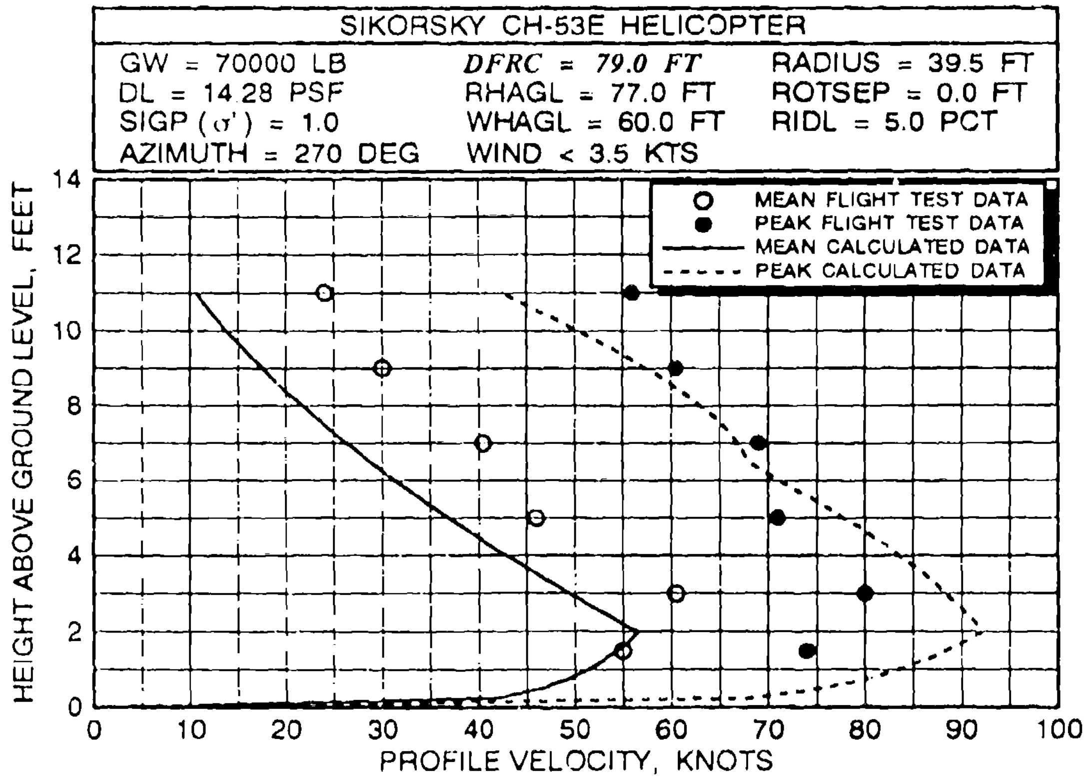
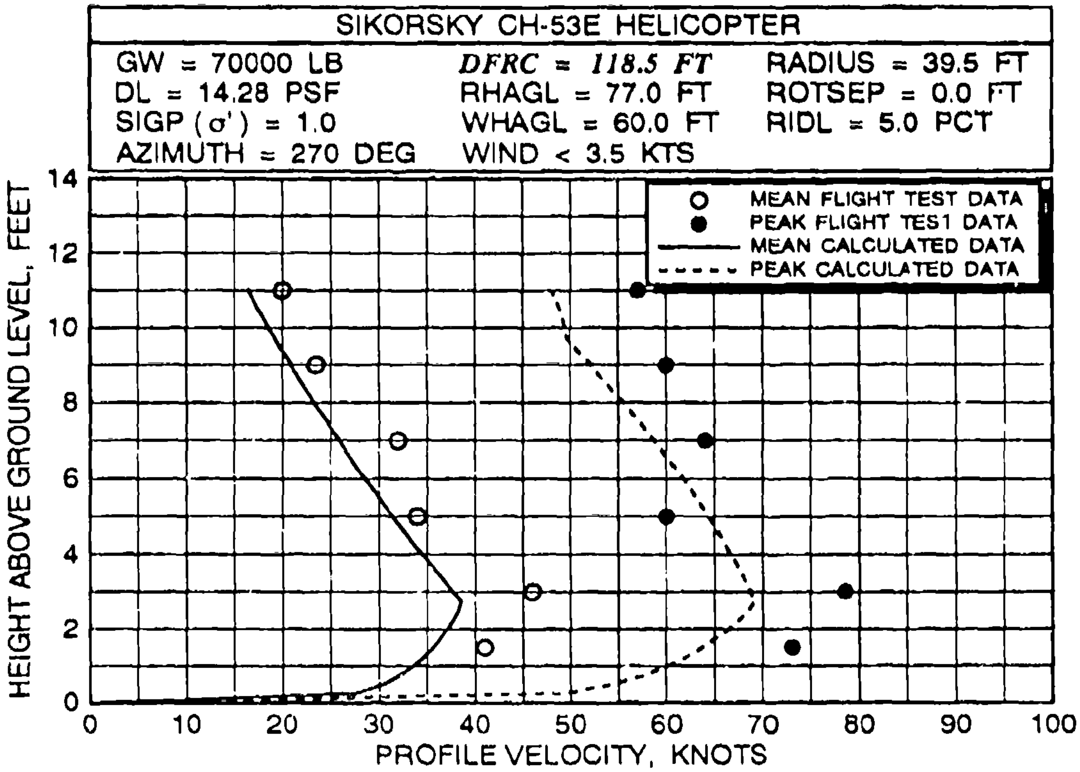


FIGURE B-3 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



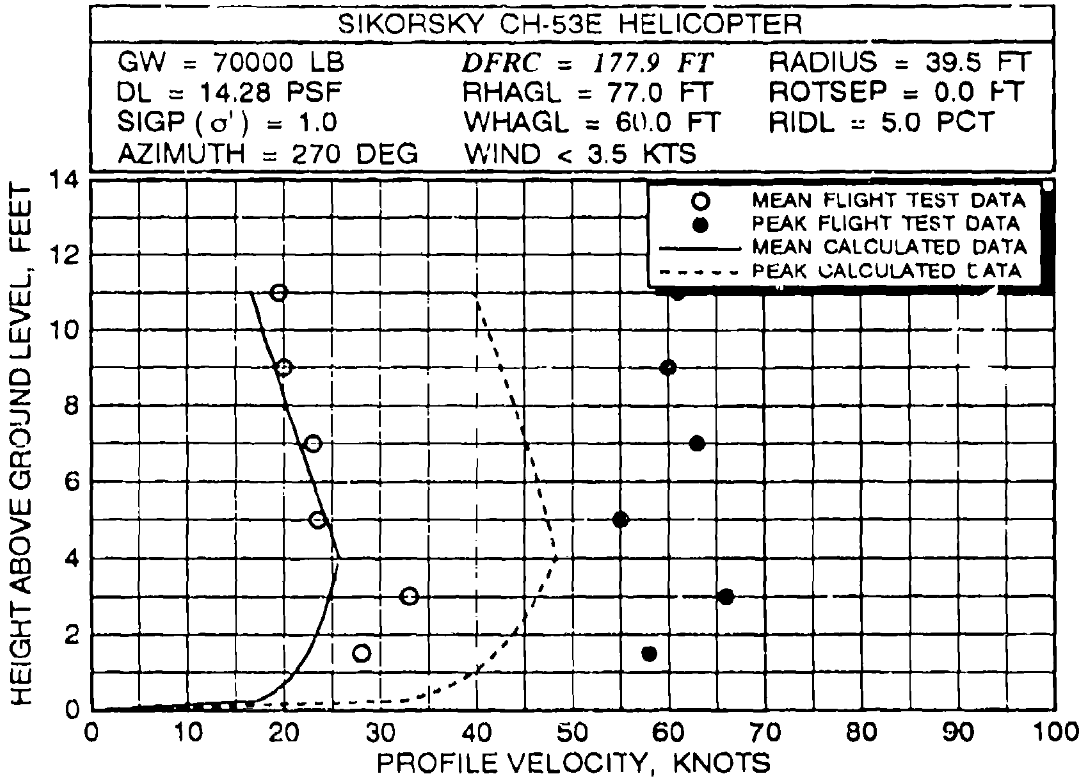
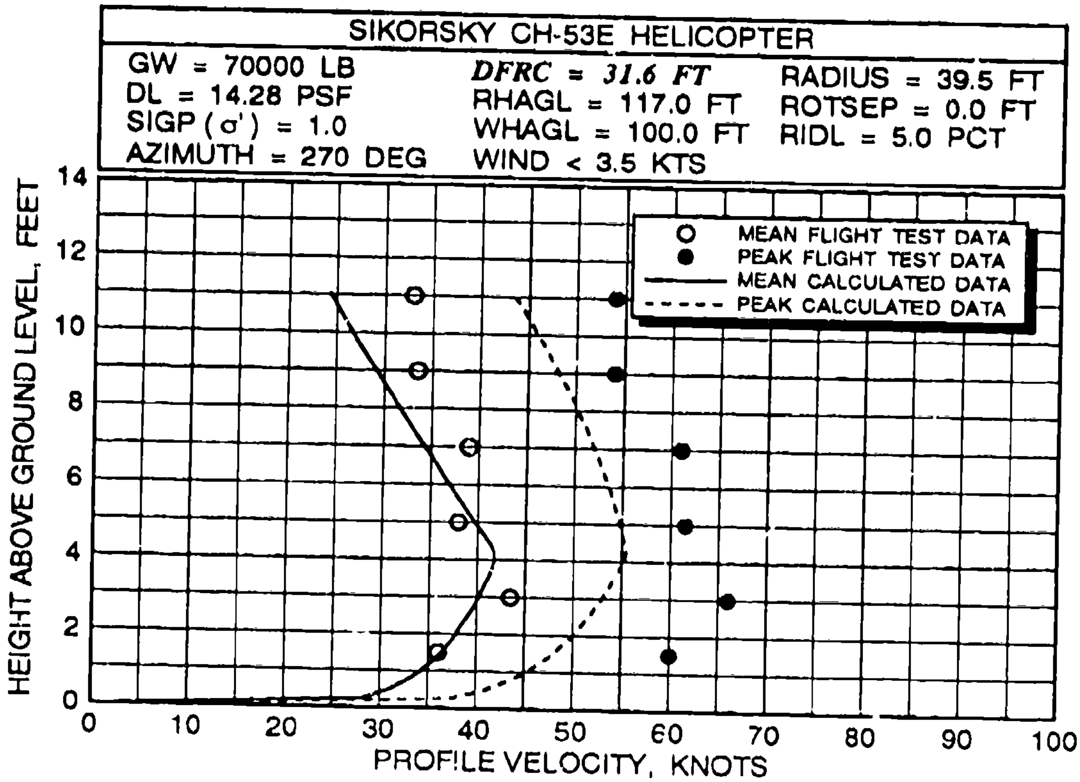


FIGURE B-3 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



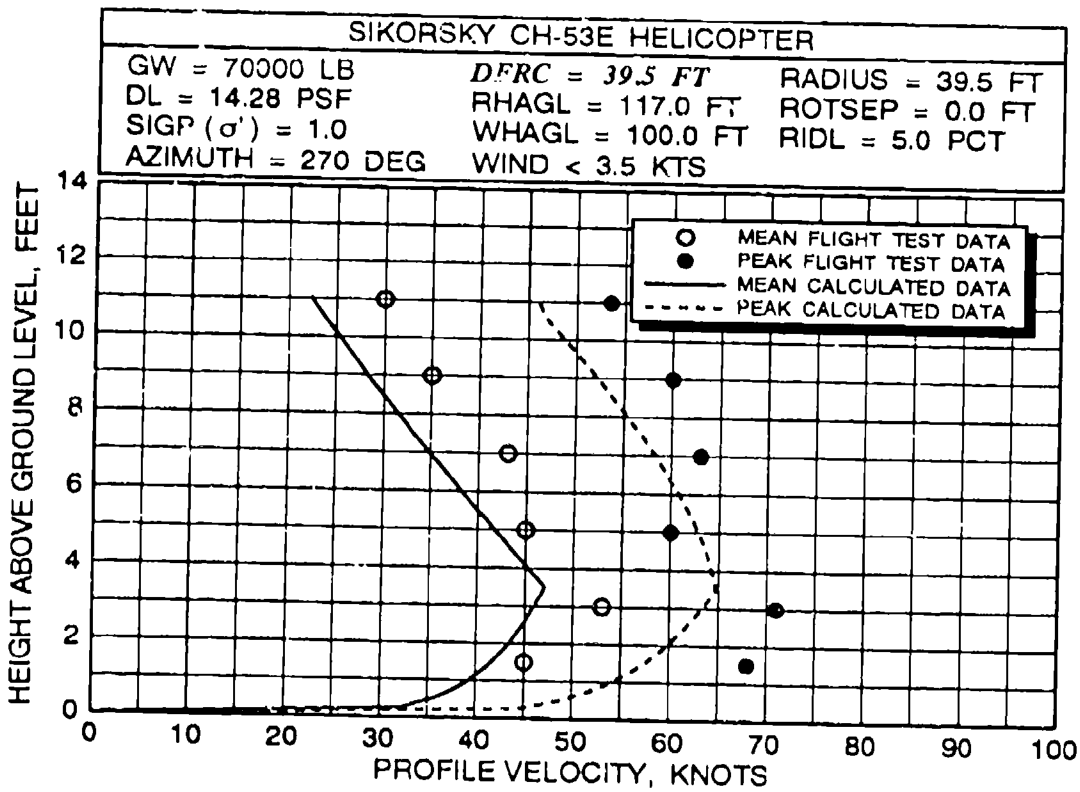
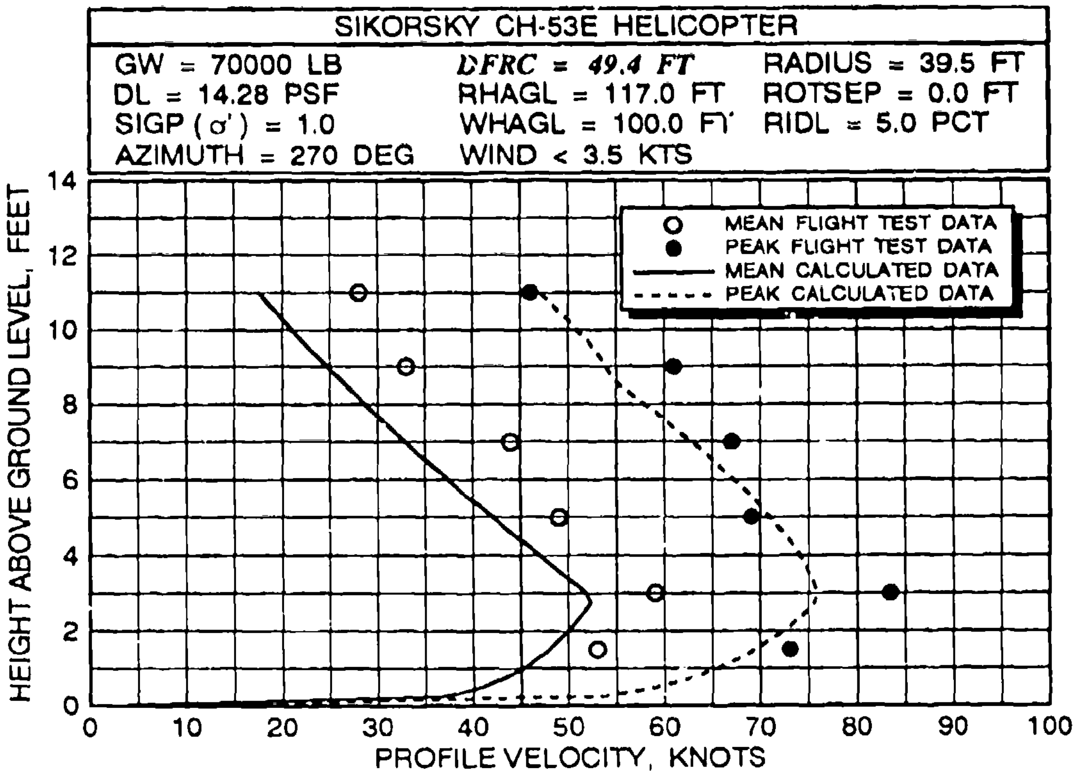


FIGURE B-4 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 70,000 POUNDS



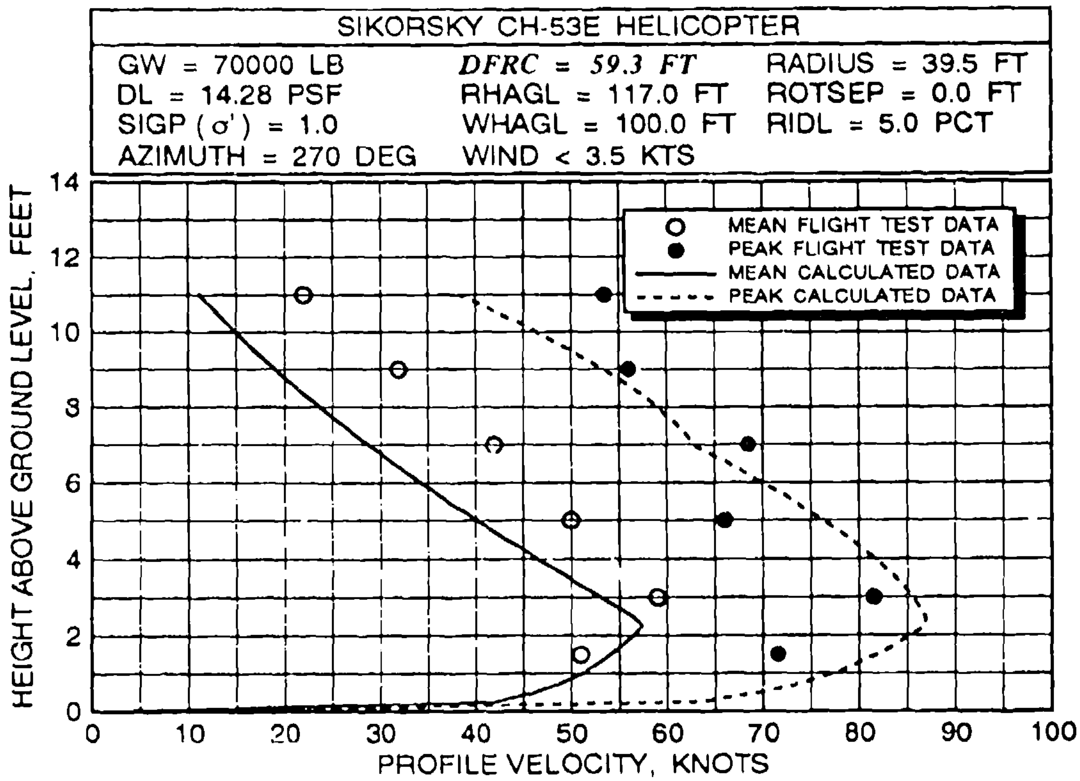
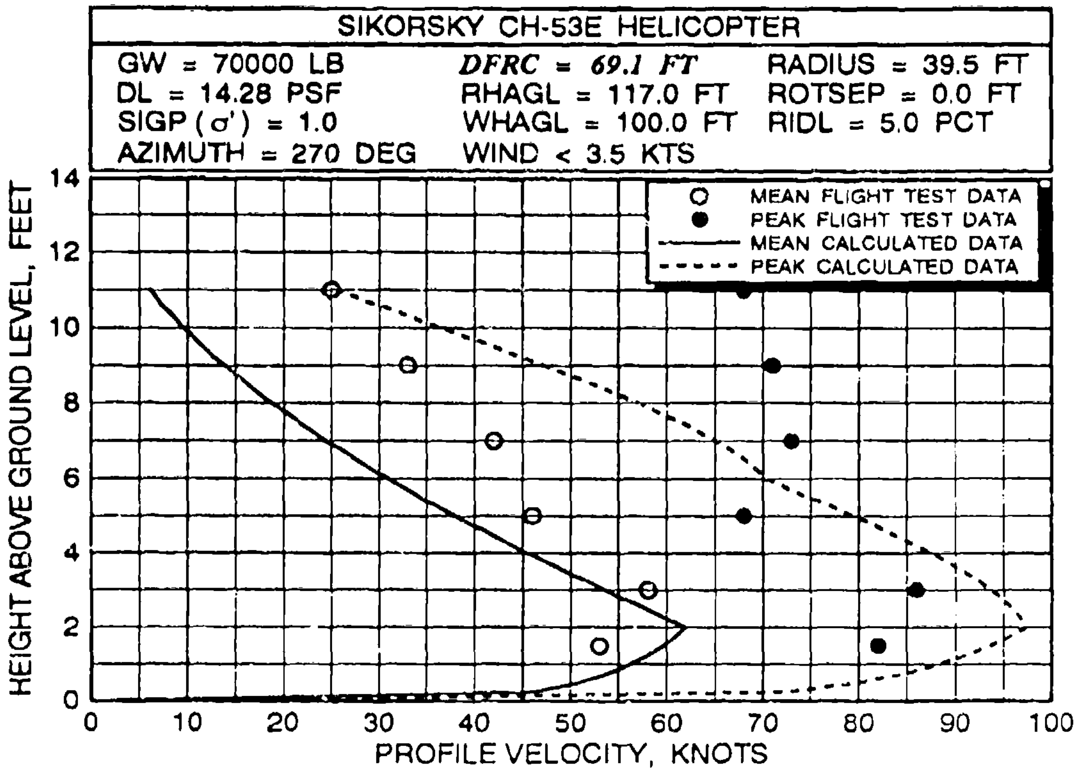


FIGURE B-4 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



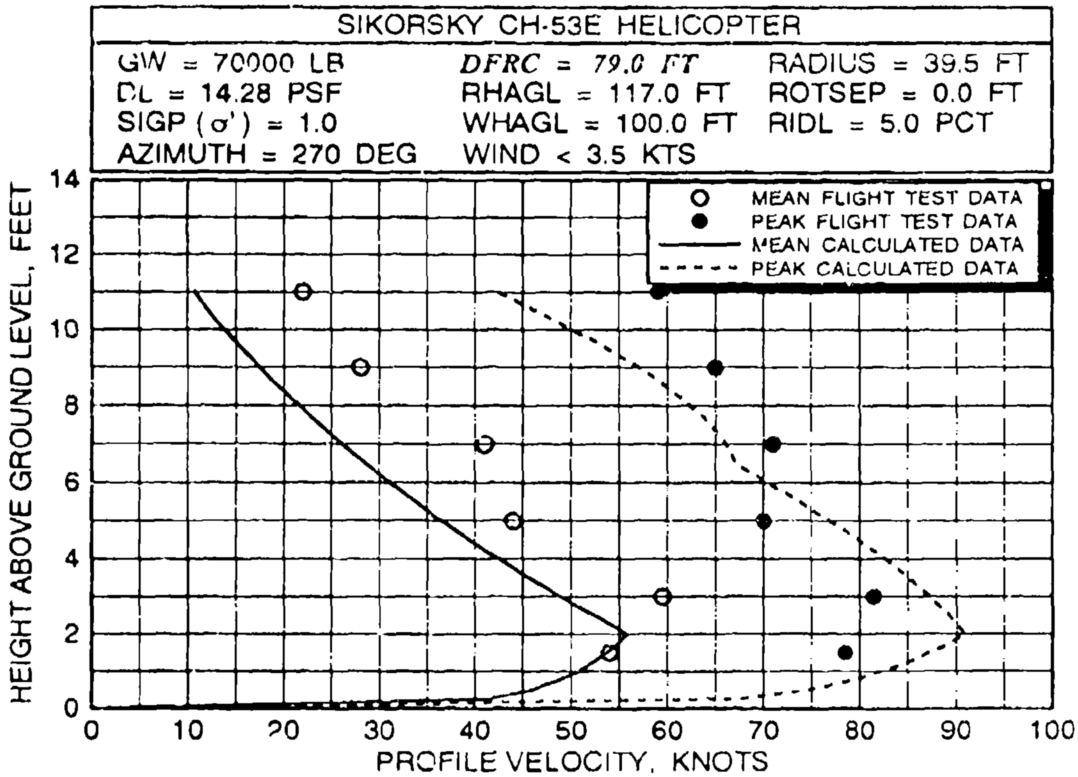
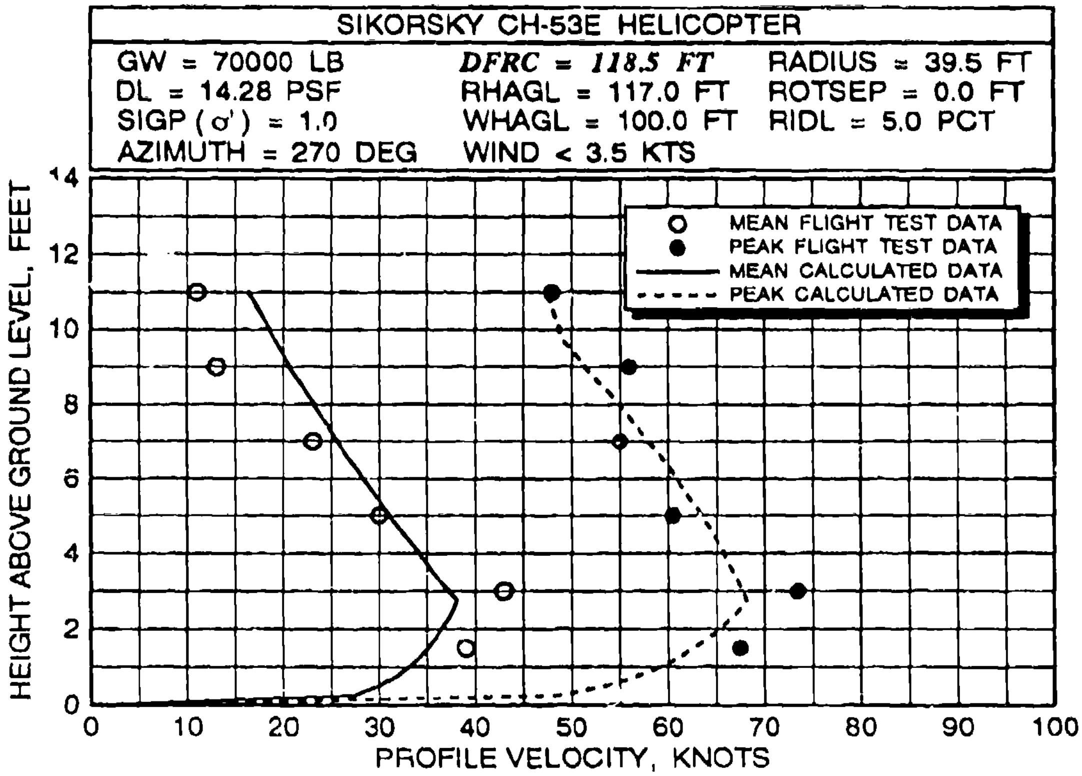


FIGURE B-4 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



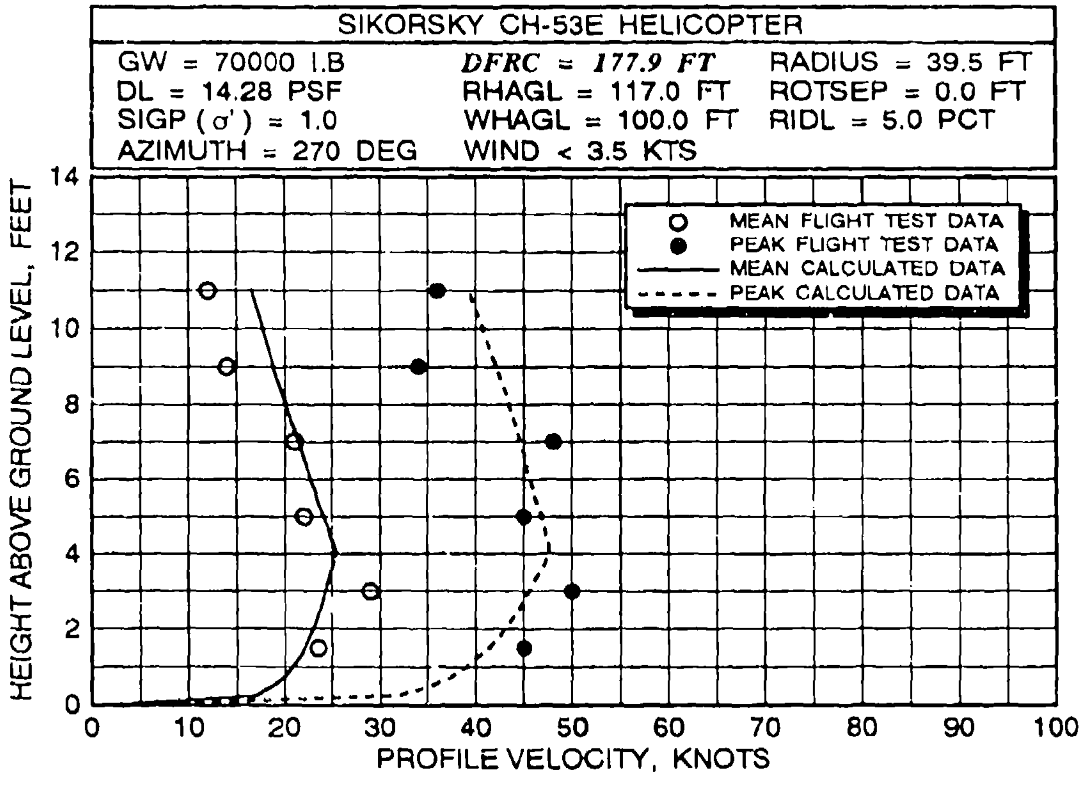
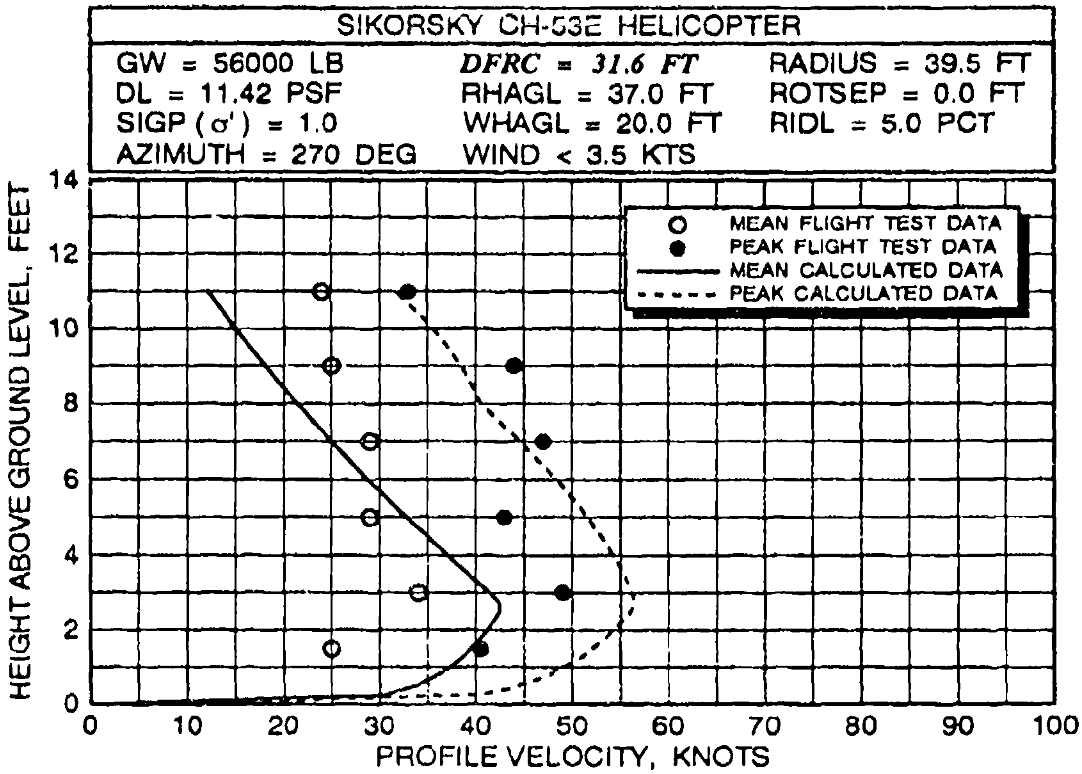


FIGURE B-4 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 70,000 POUNDS (continued)



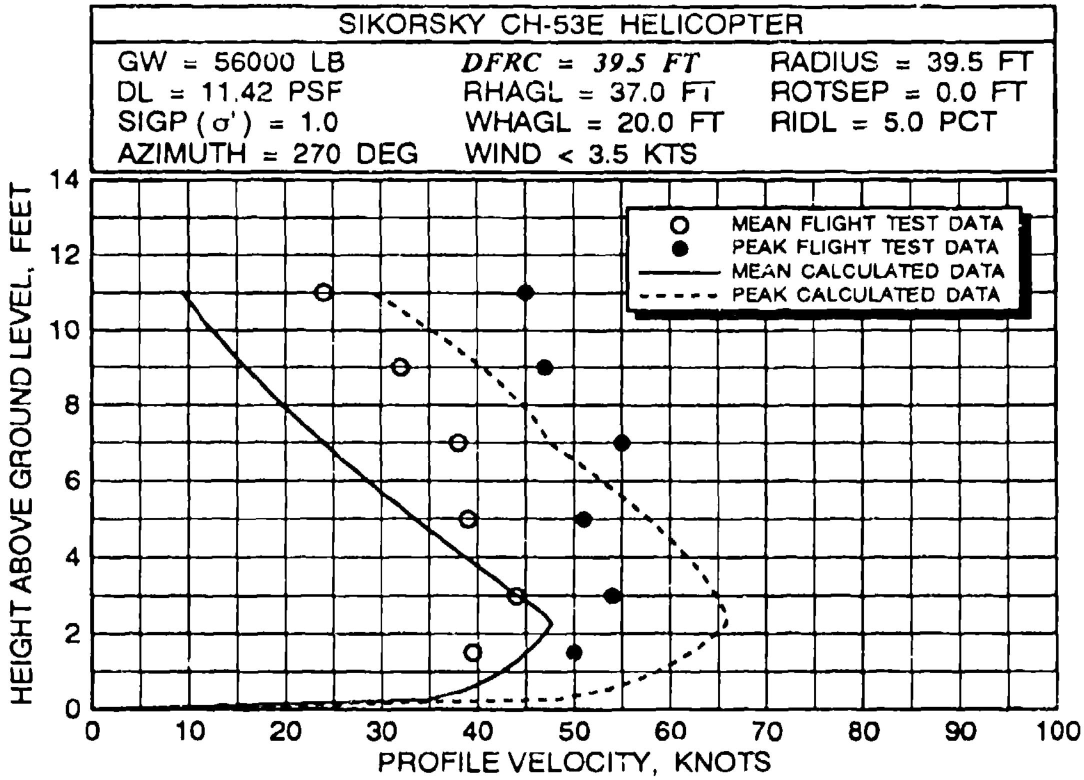
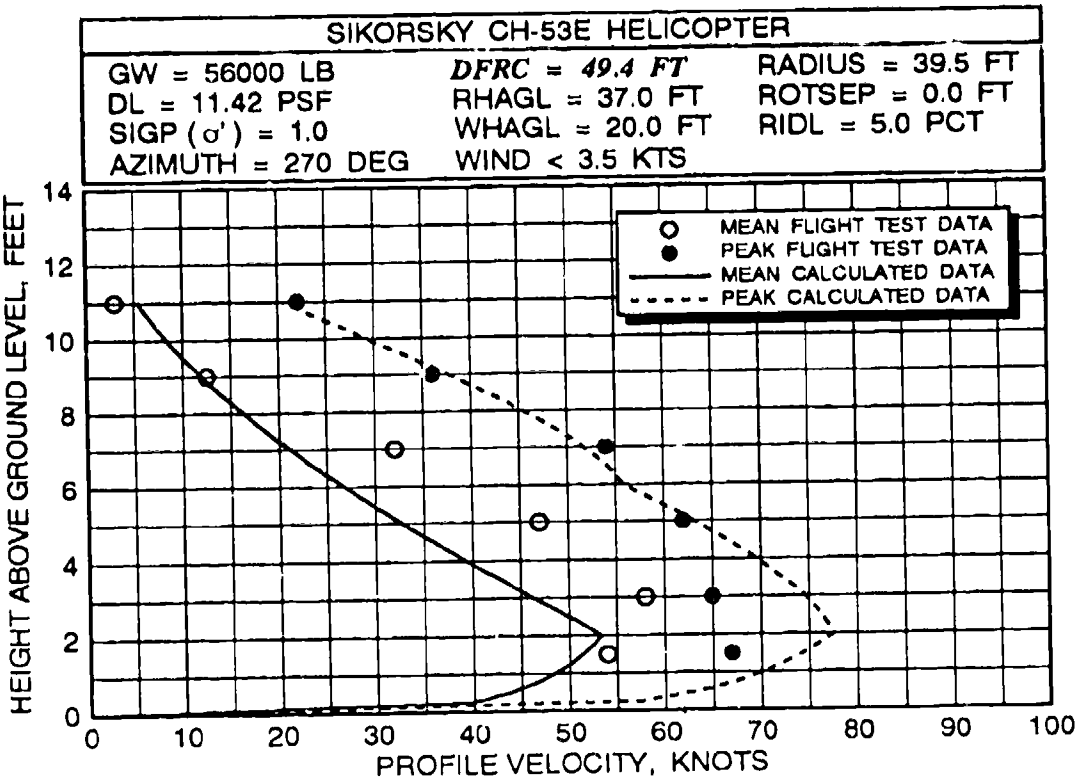


FIGURE B-5 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 56,000 POUNDS



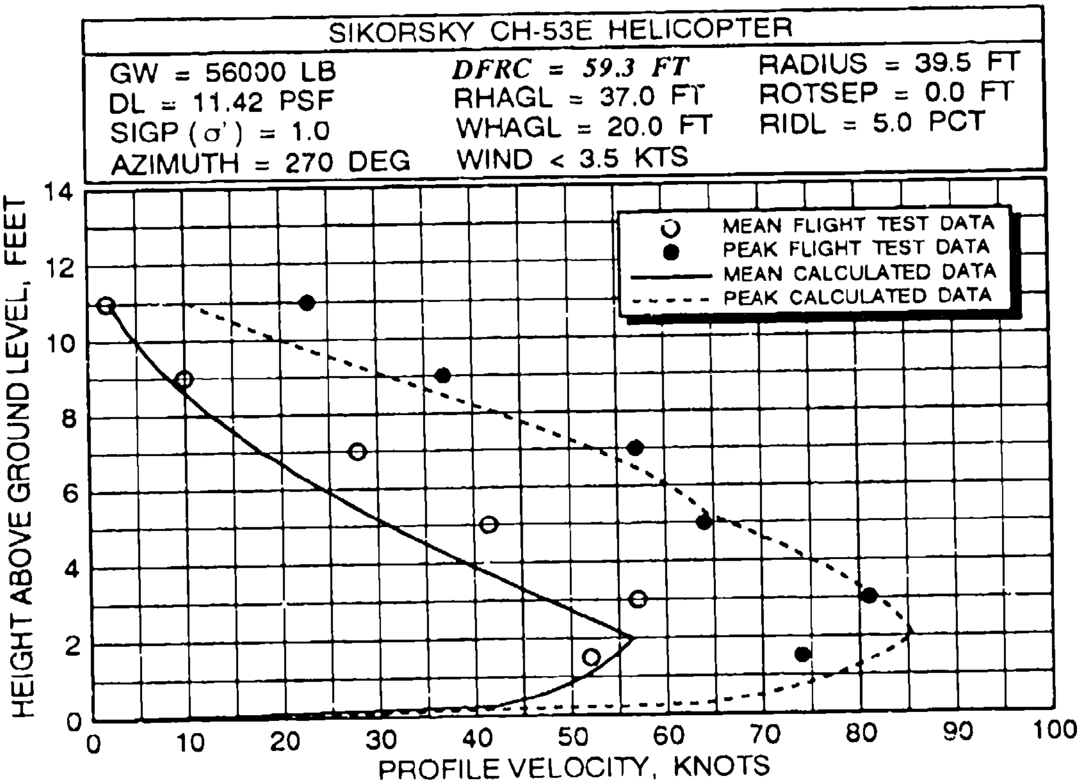
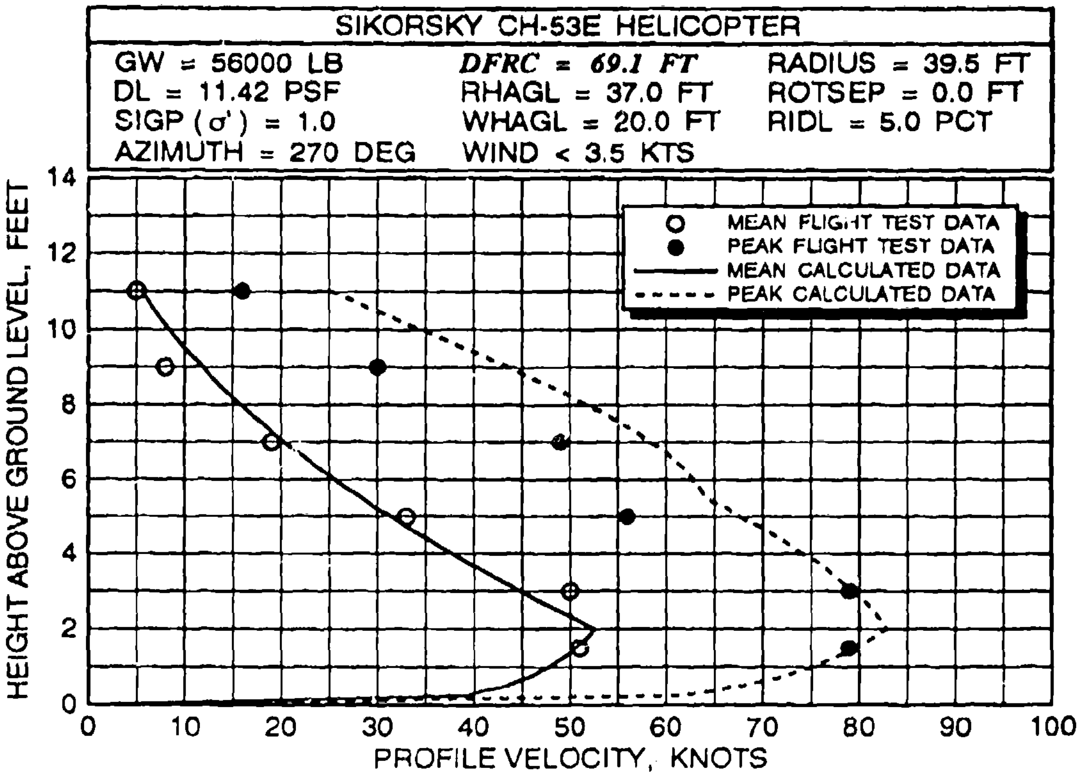


FIGURE B-5 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



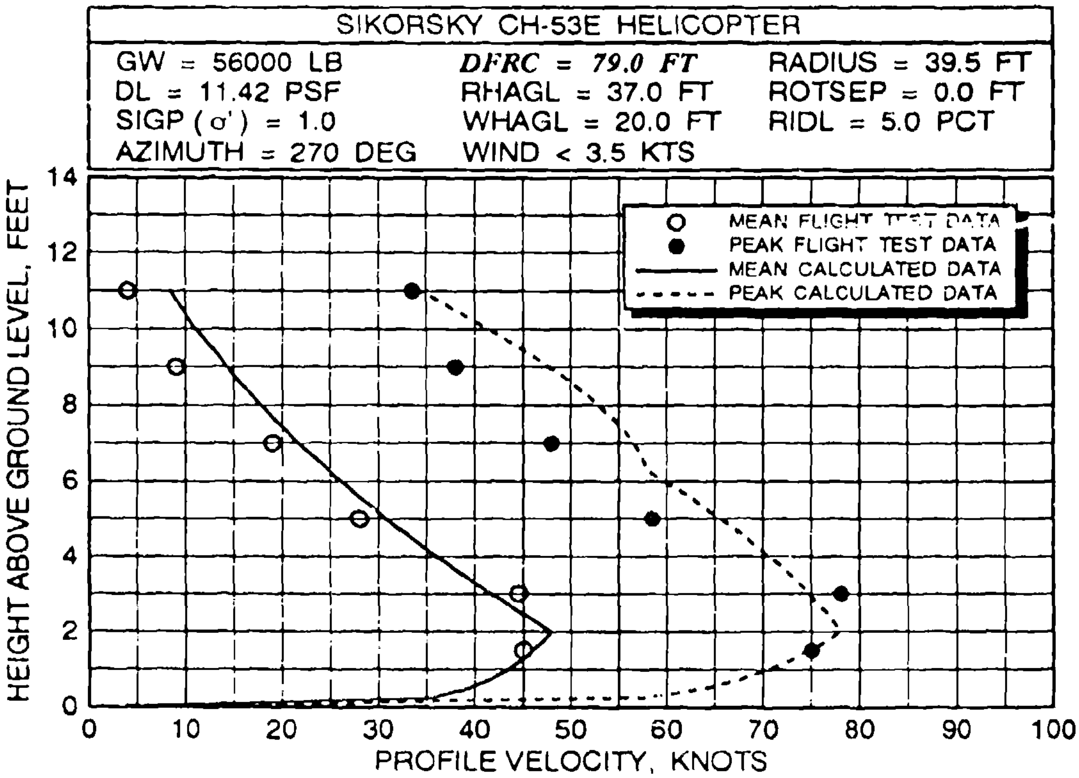
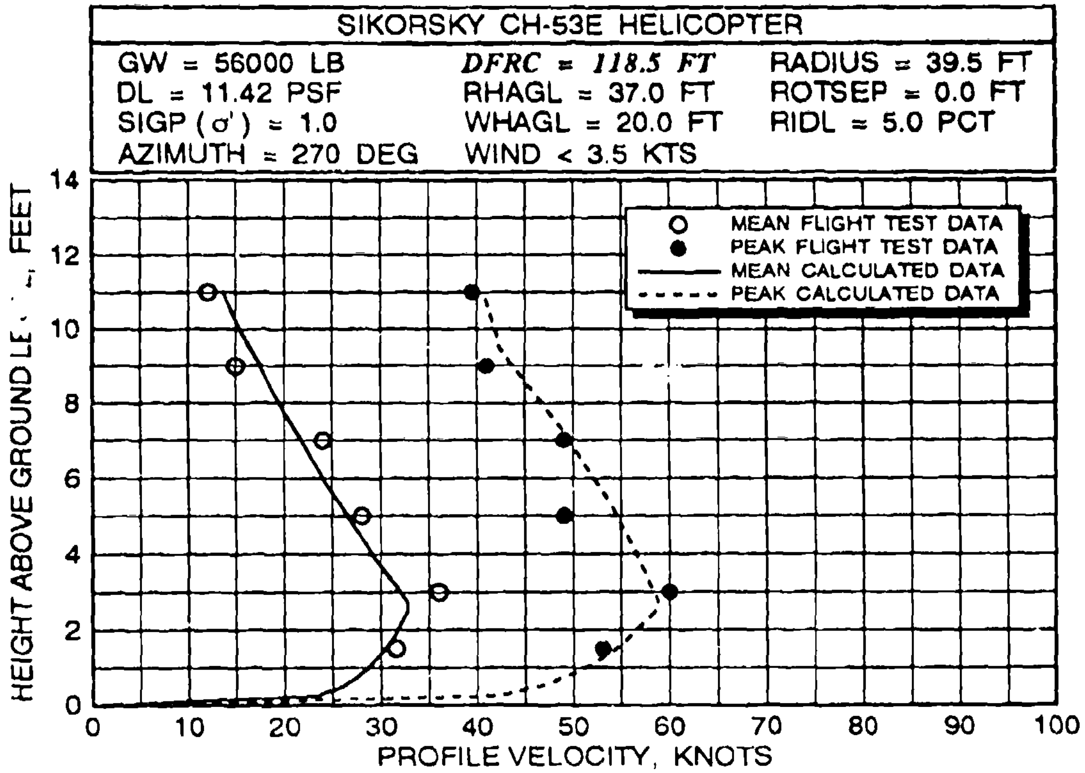


FIGURE B-5 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



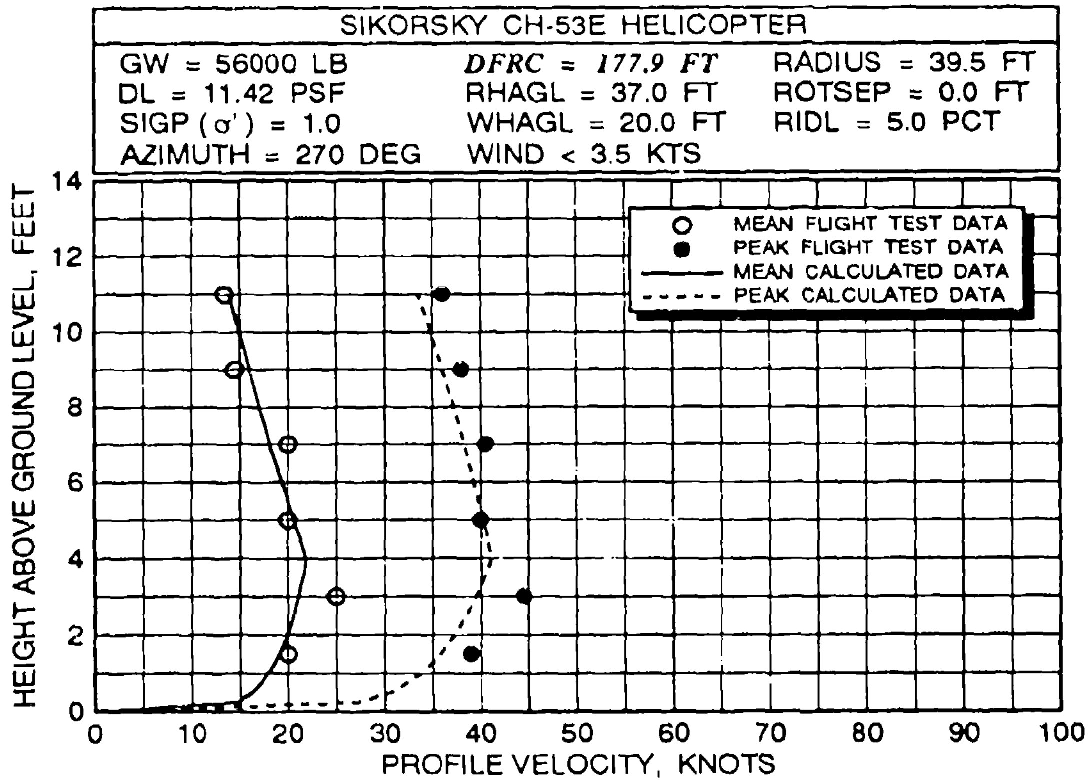
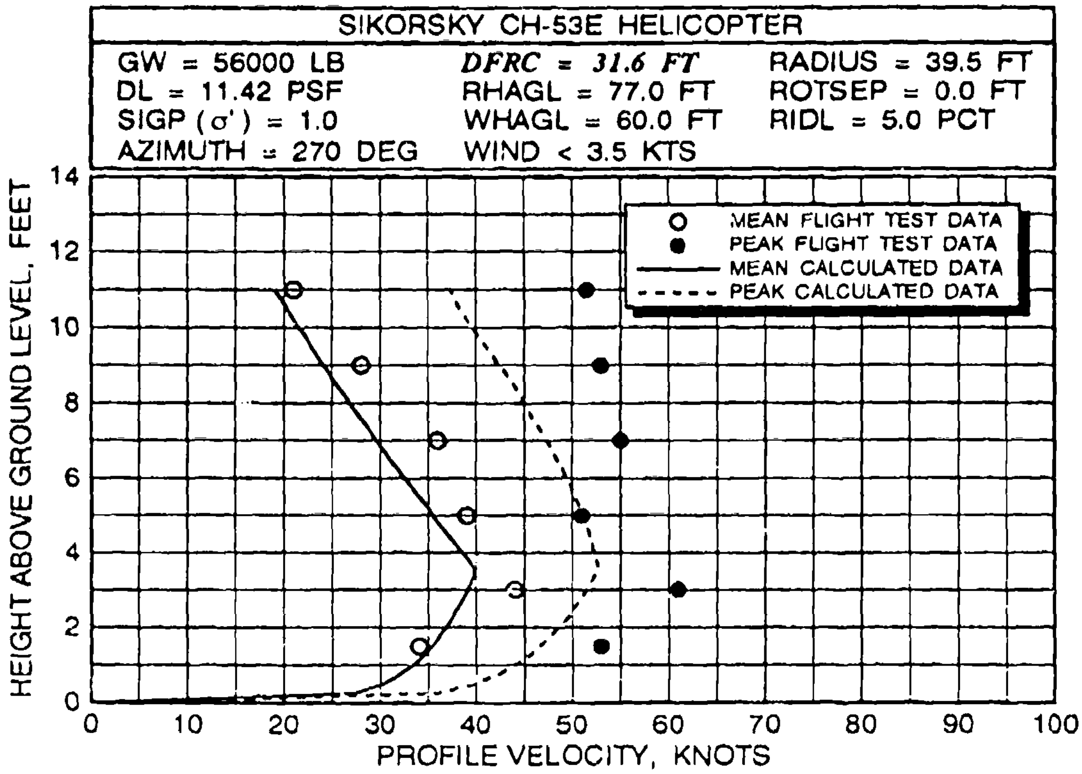


FIGURE B-5 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



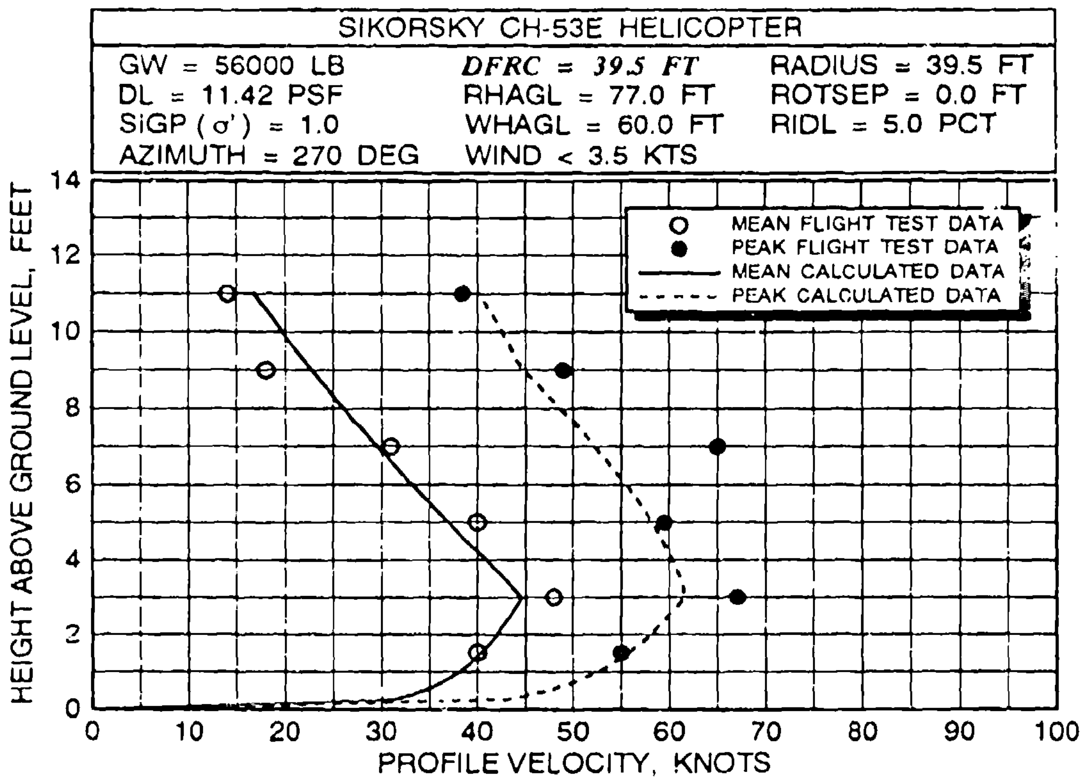
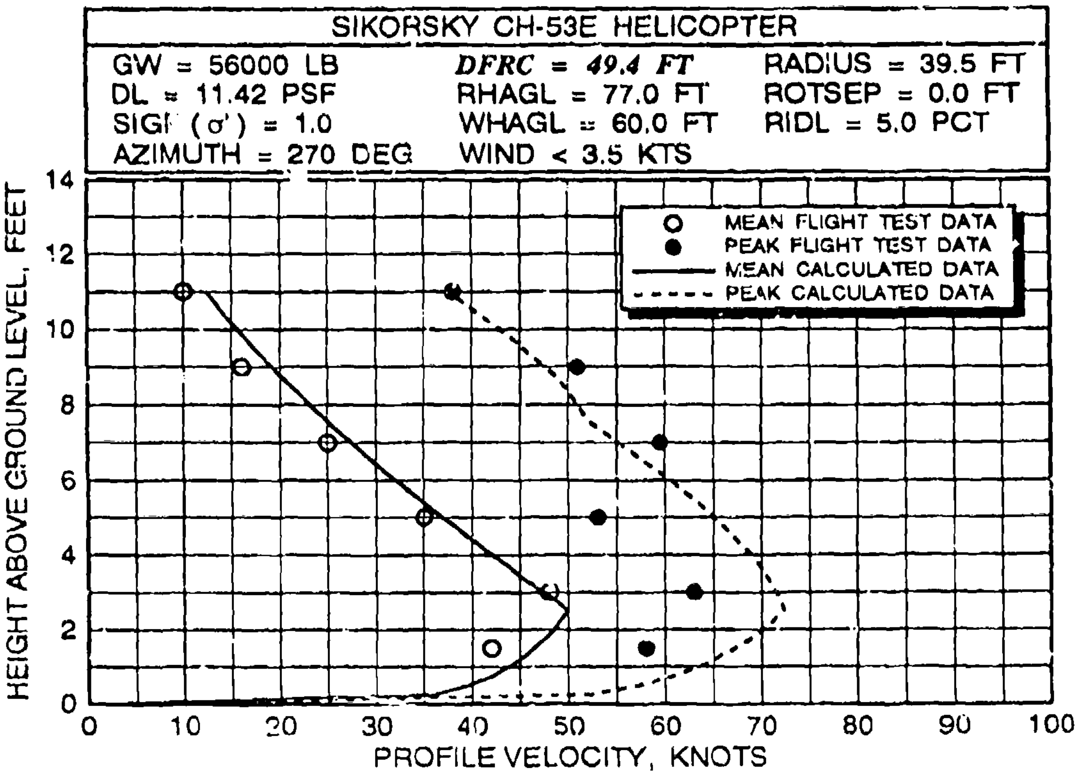


FIGURE B-6 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



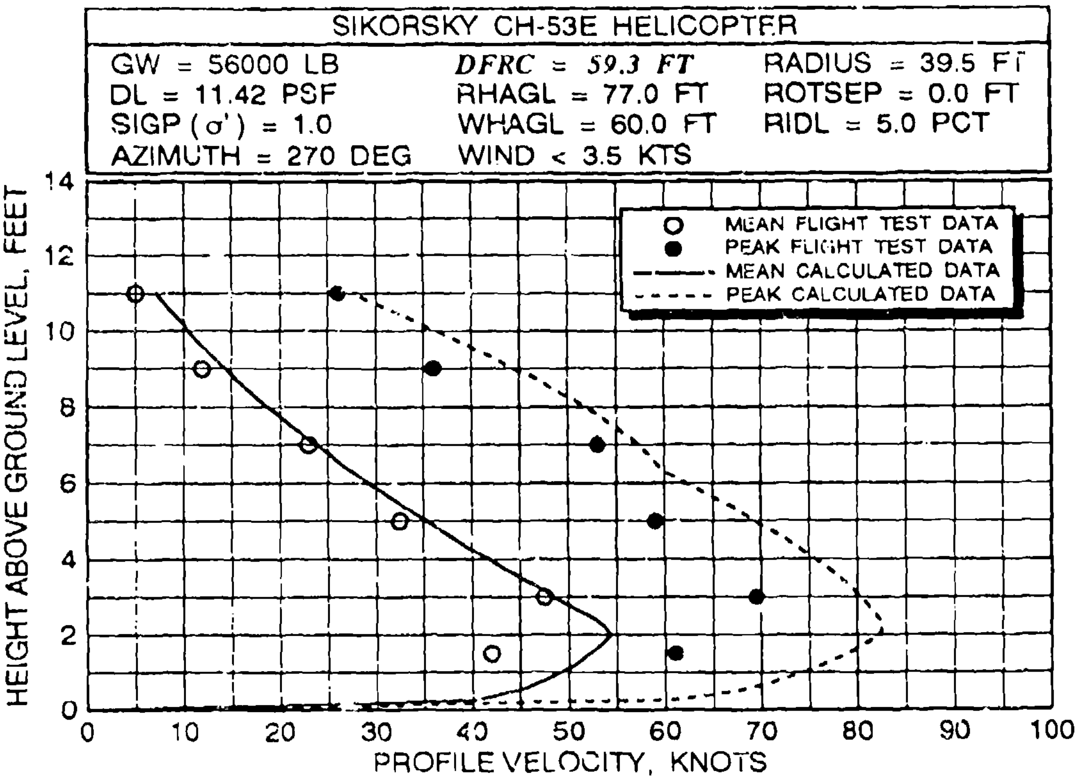
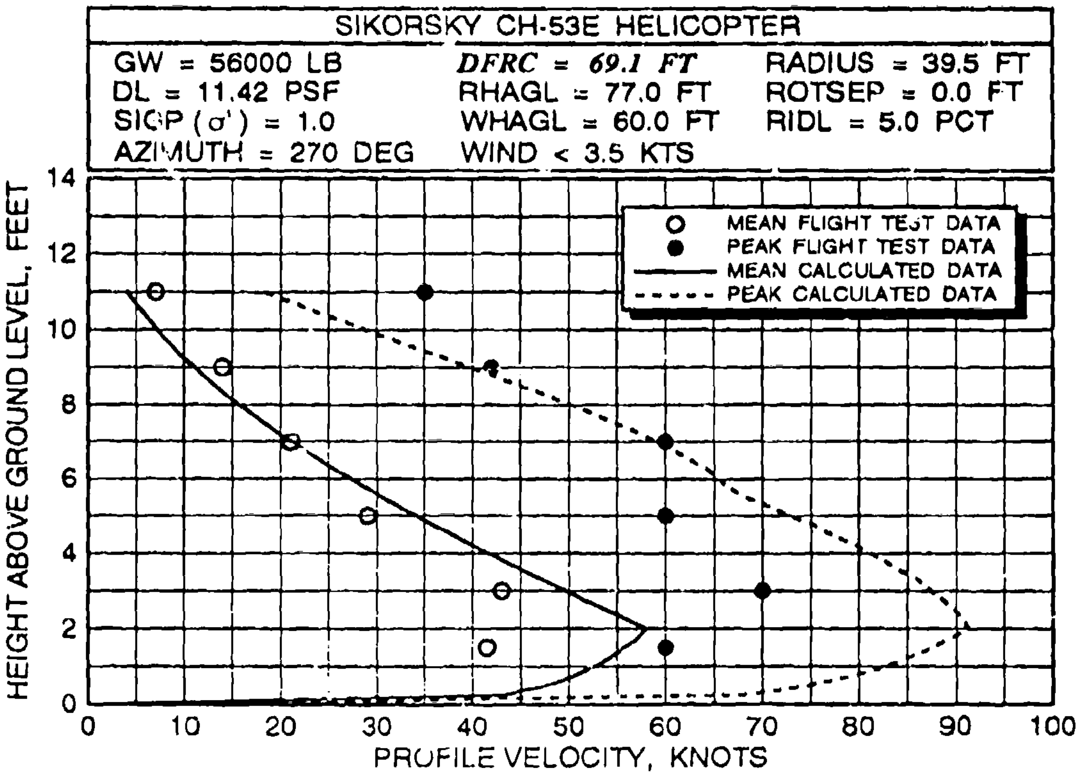


FIGURE B-6 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



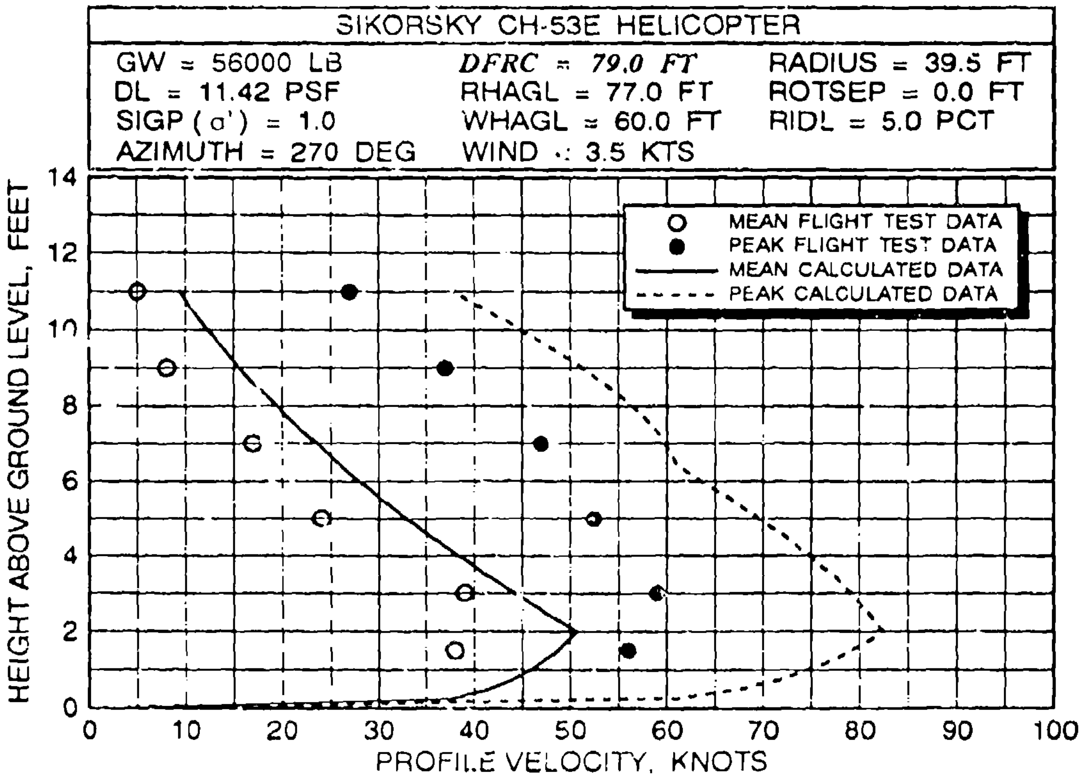
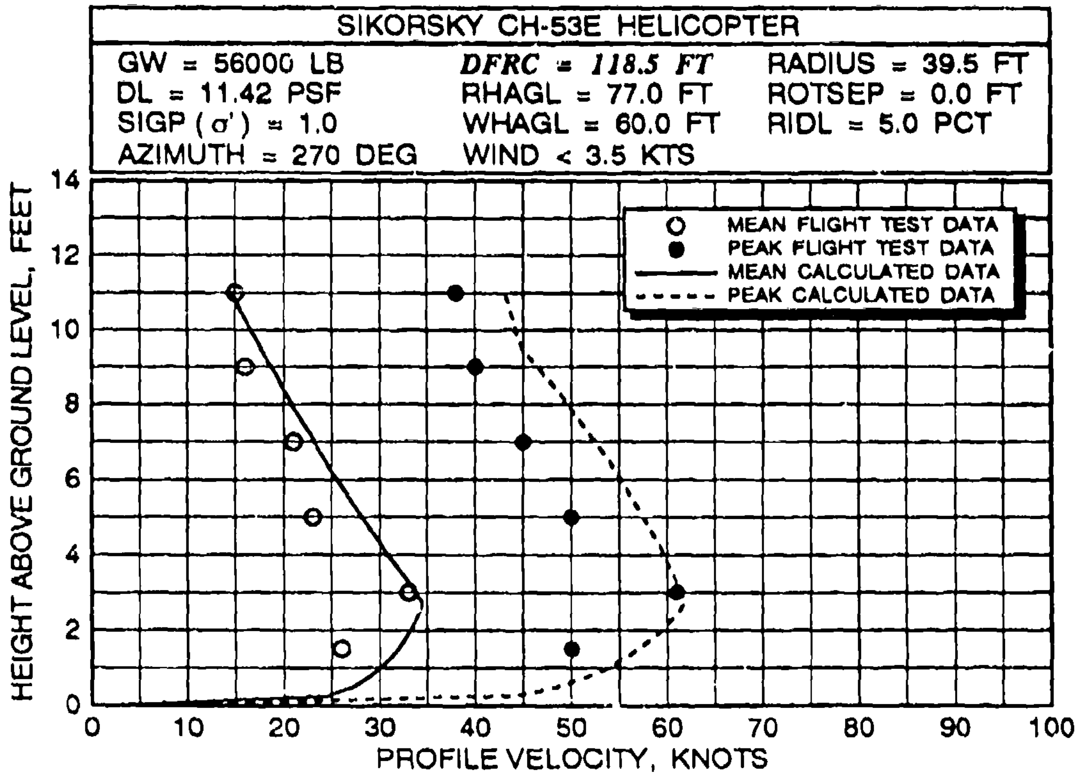


FIGURE B-6 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



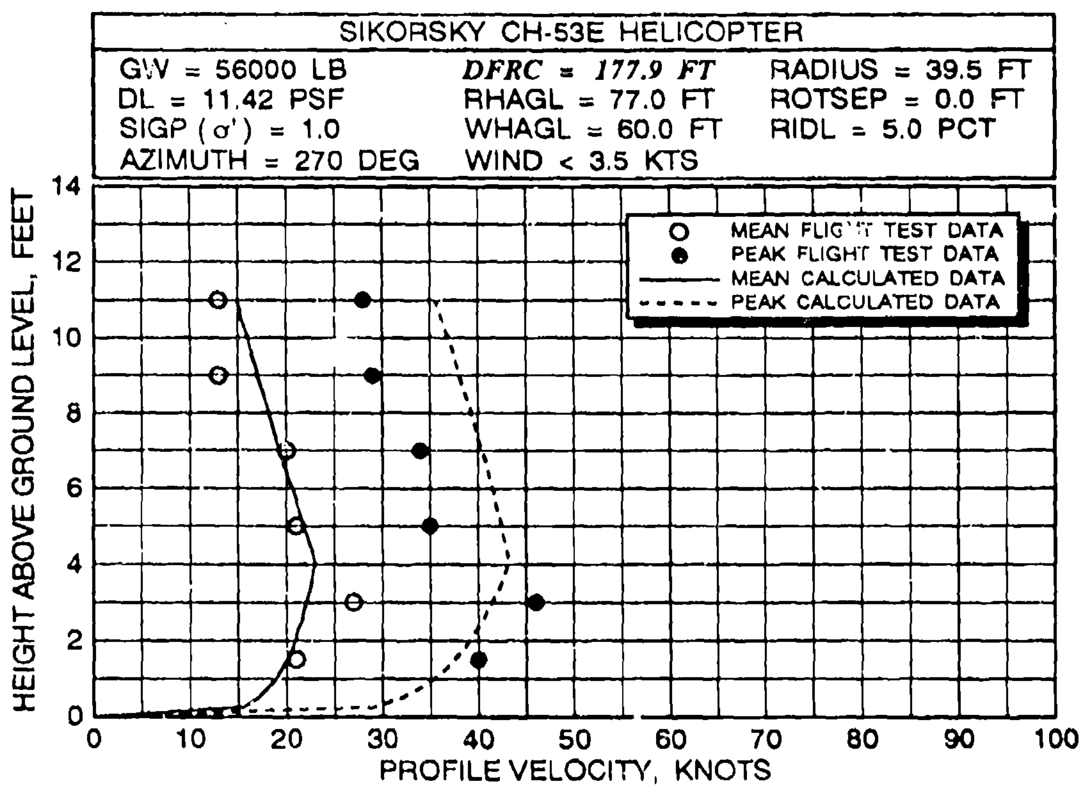
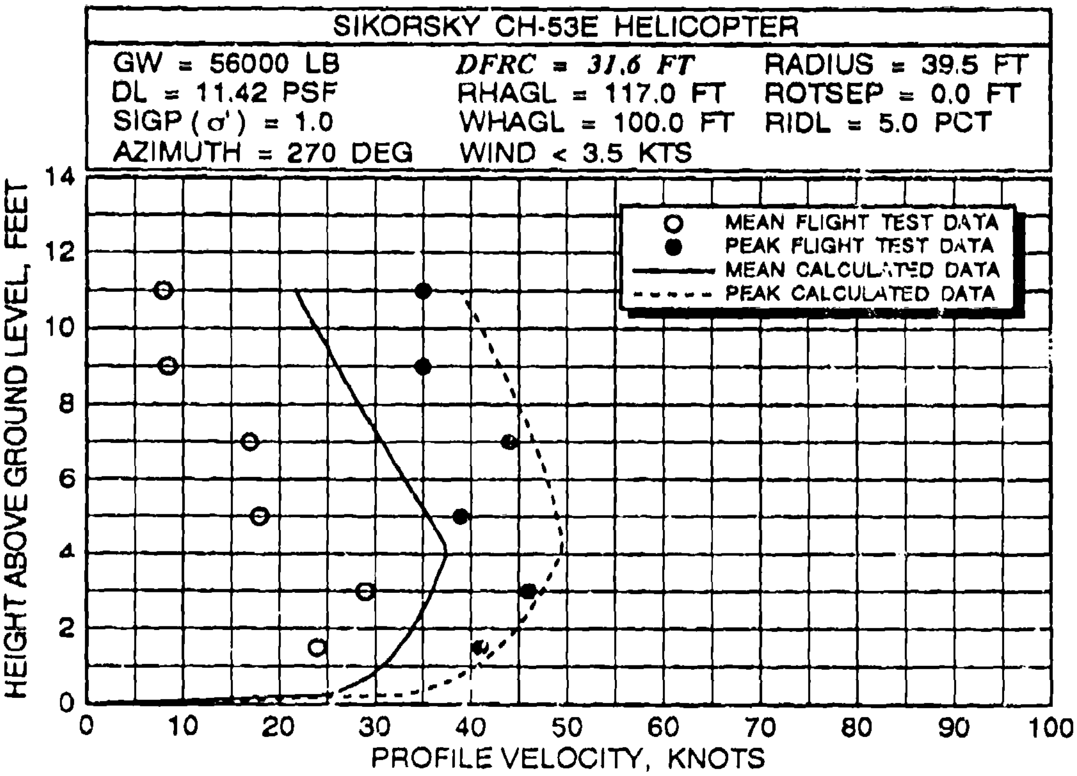


FIGURE B-6 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



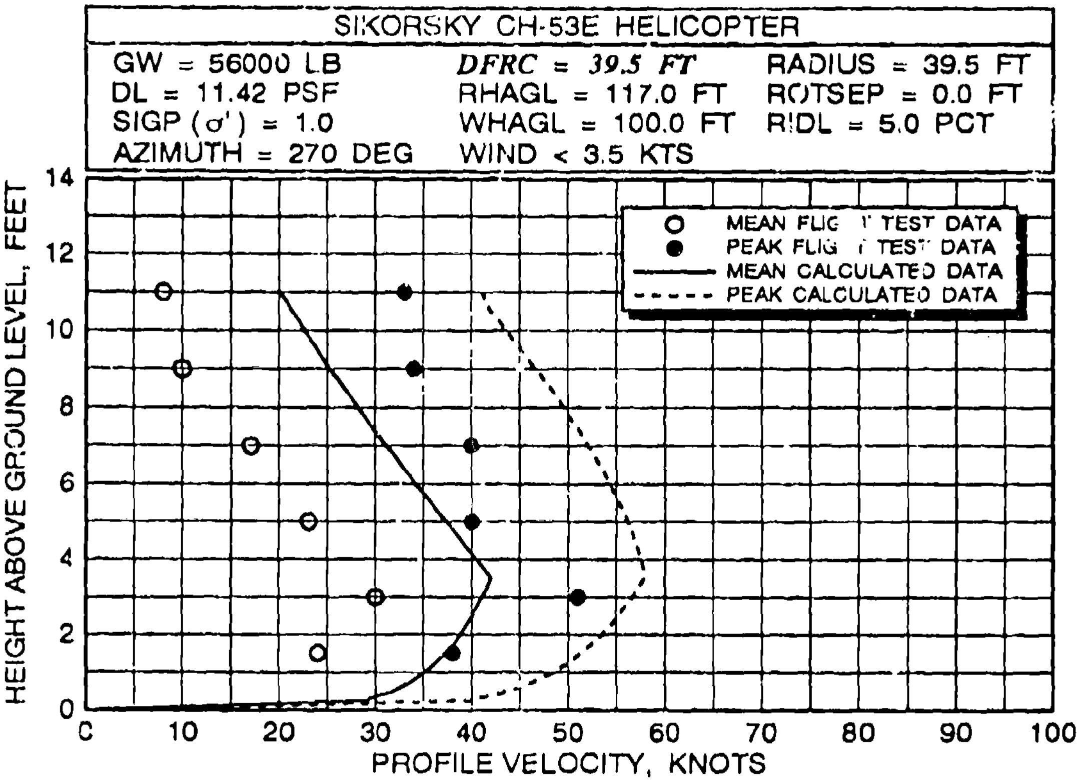
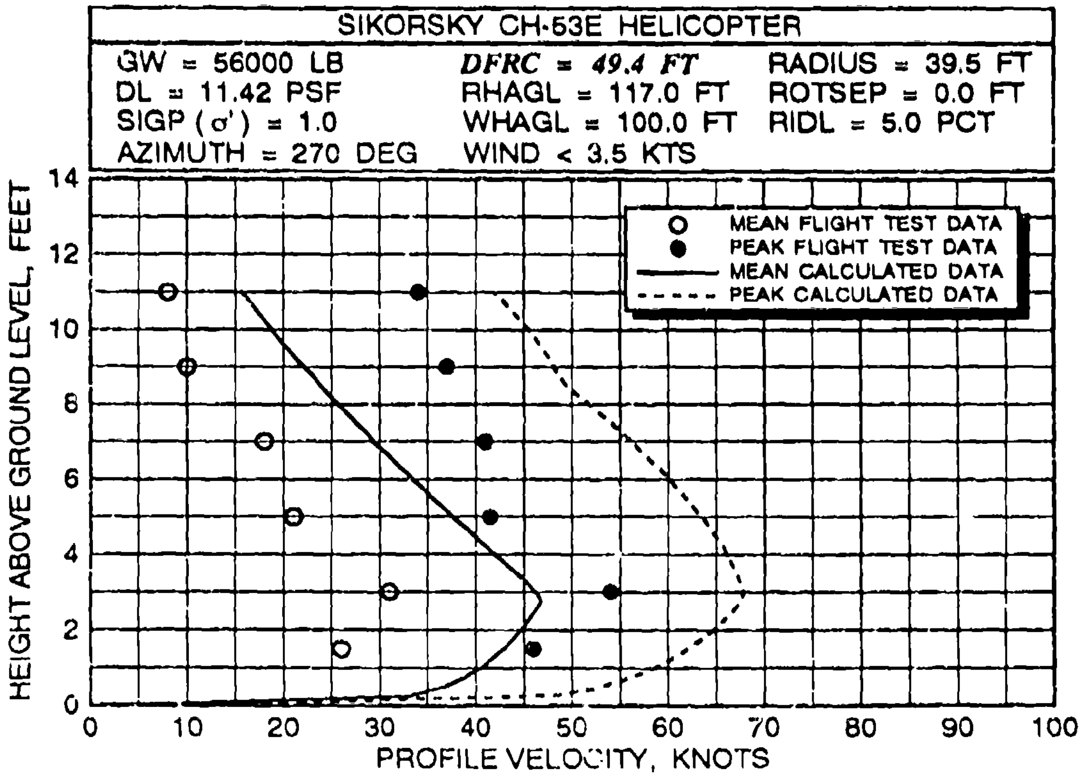


FIGURE B-7 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 56,000 POUNDS



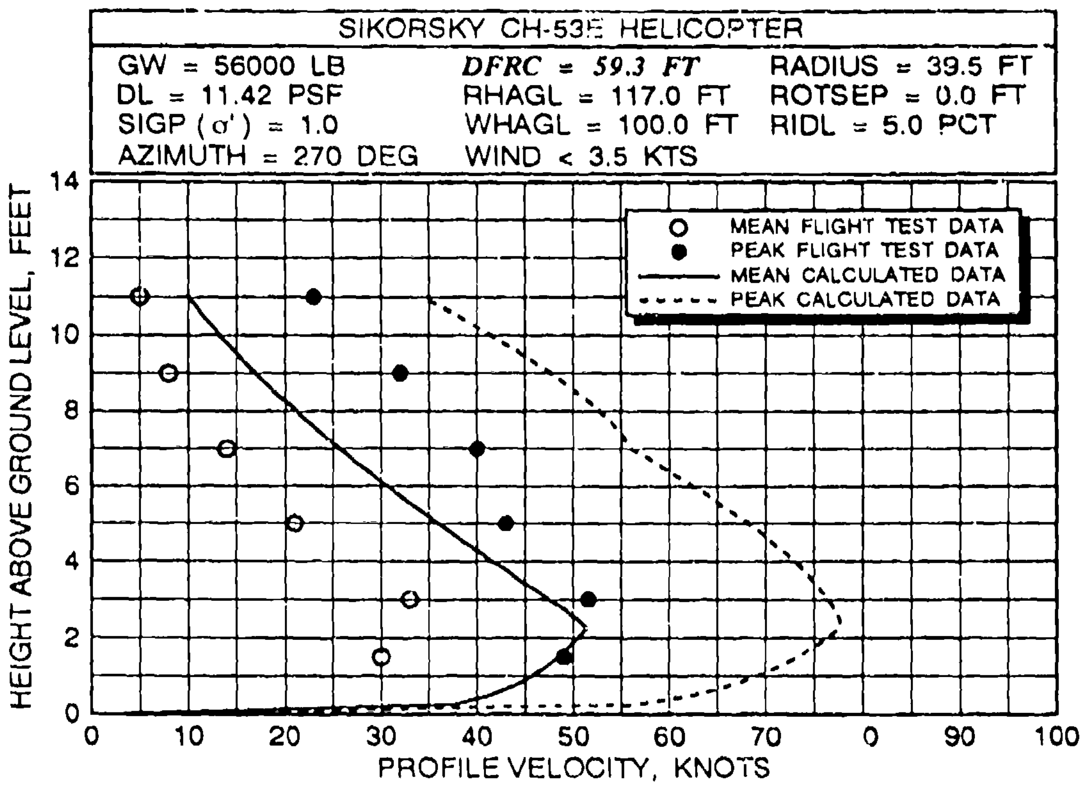
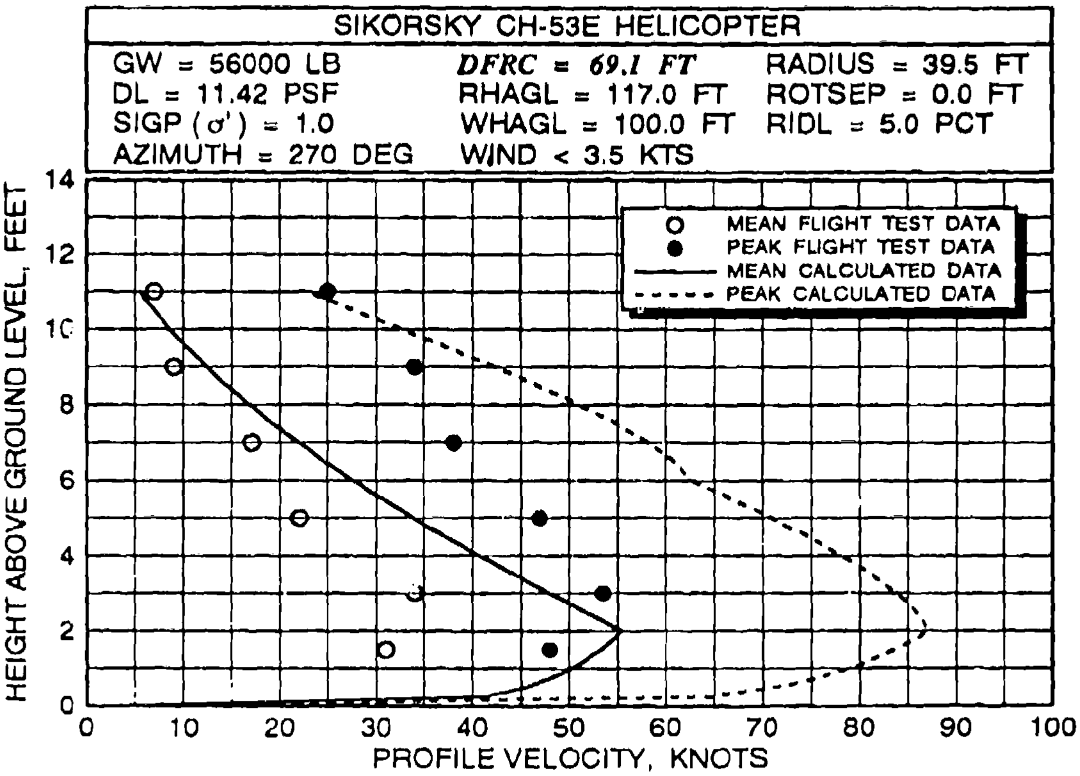


FIGURE B-7 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 56,000 POUNDS (continued)



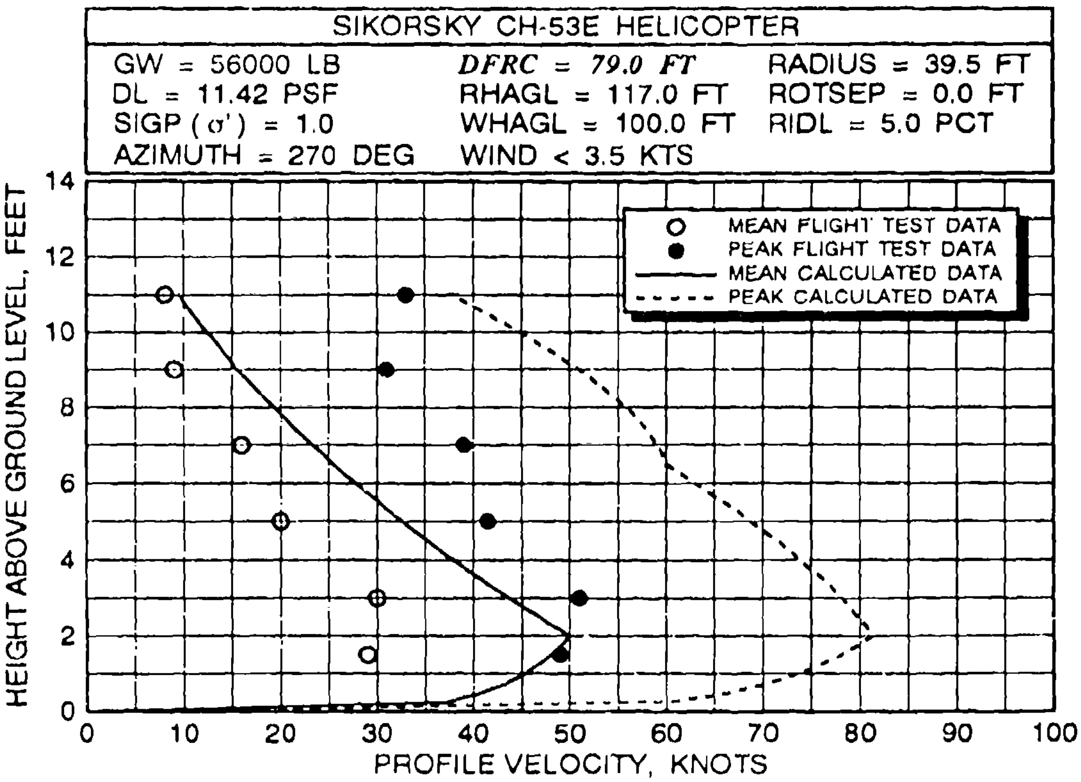
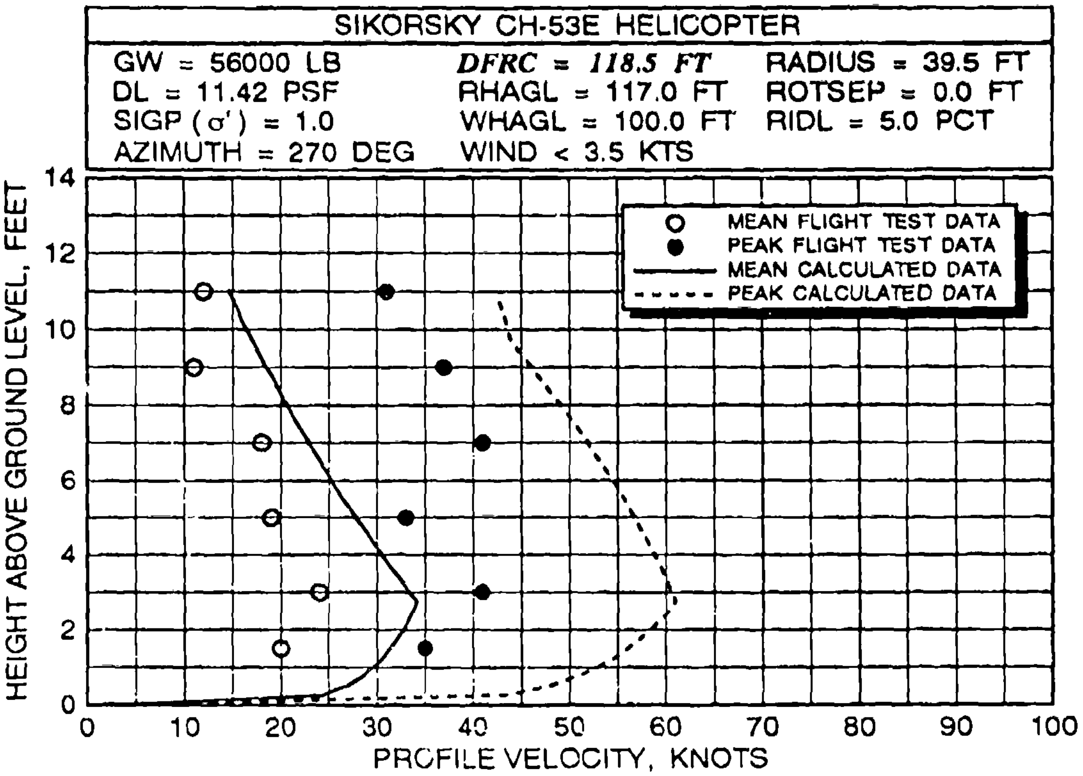


FIGURE B-7 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



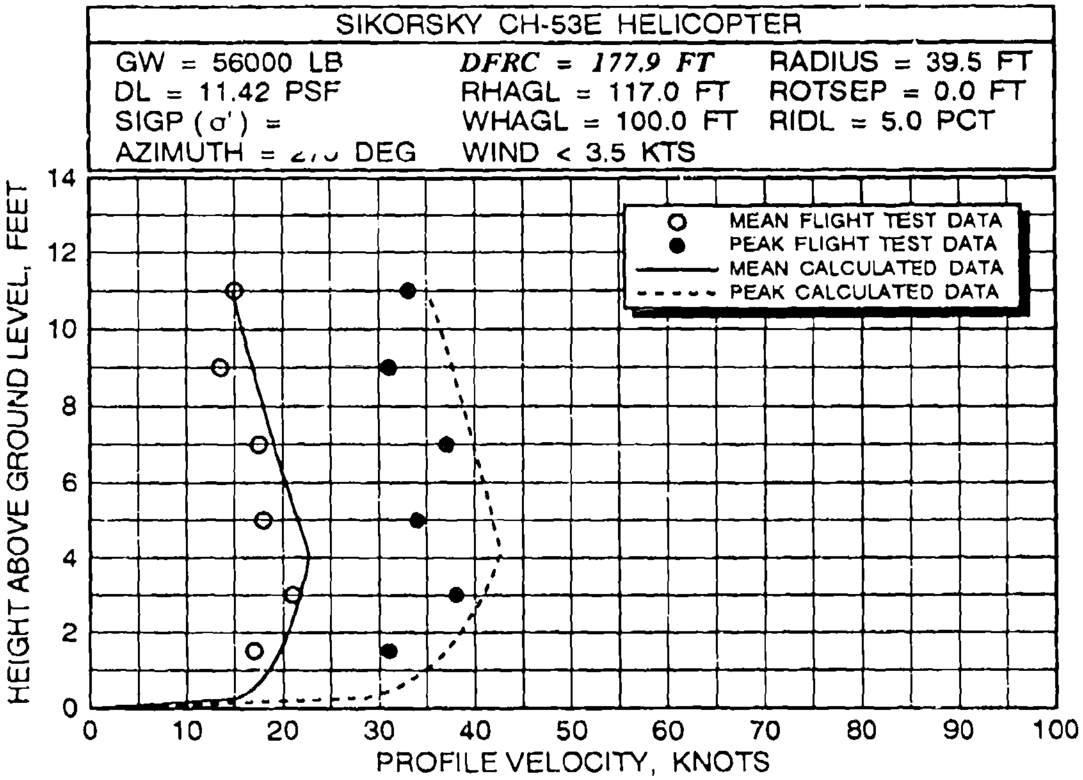
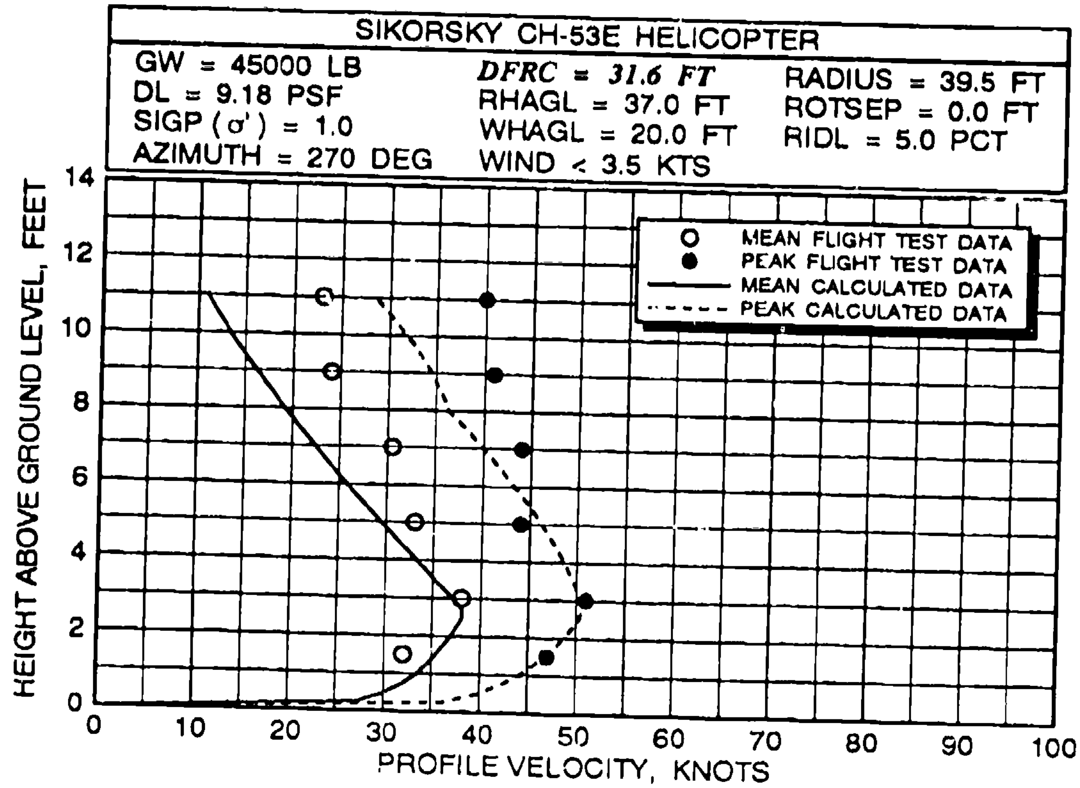


FIGURE B-7 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



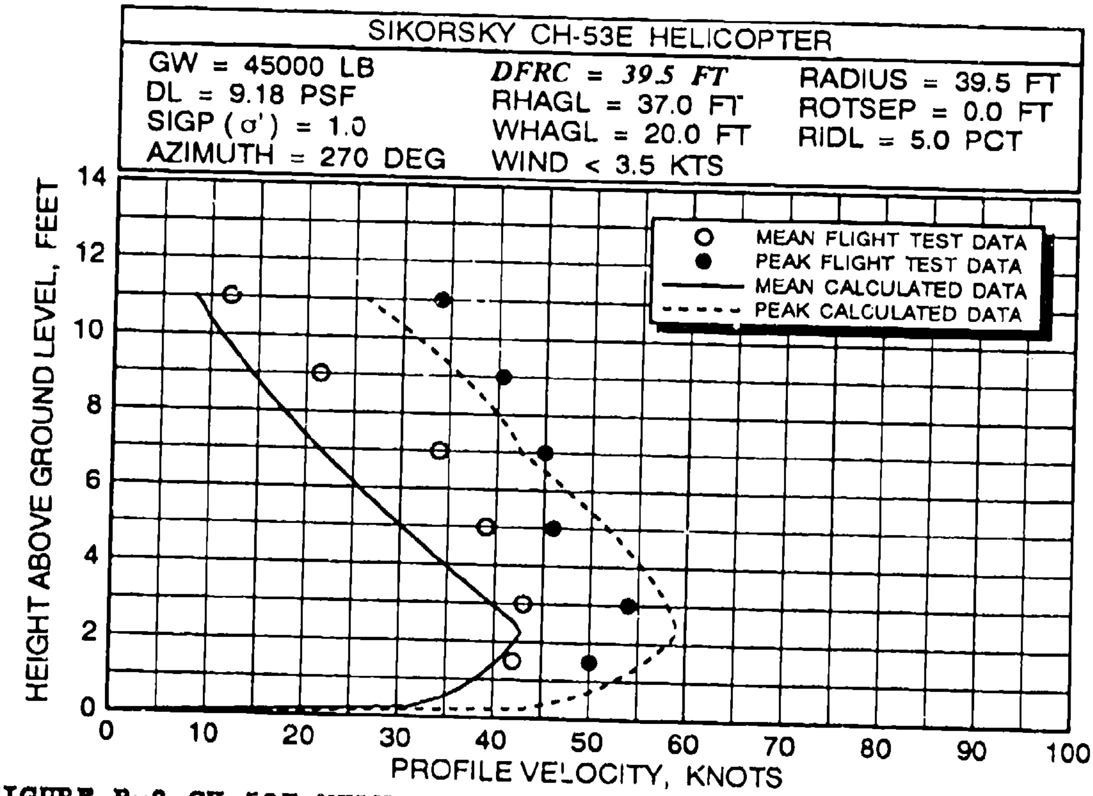
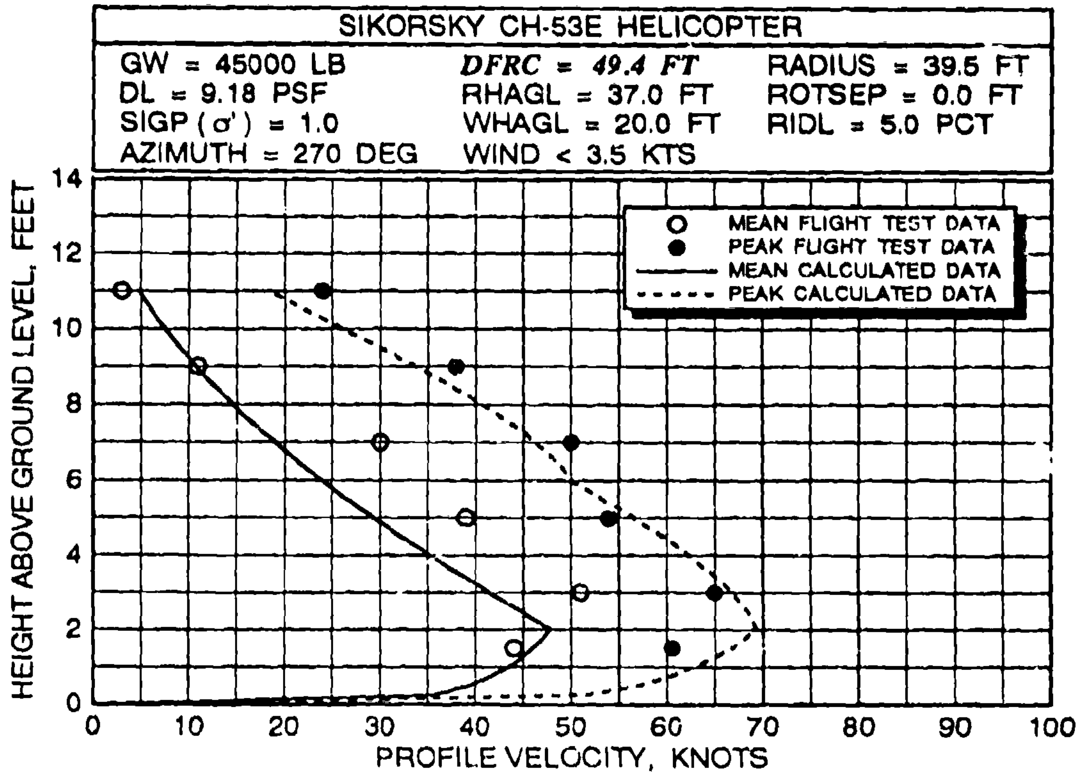


FIGURE B-8 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 45,000 POUNDS



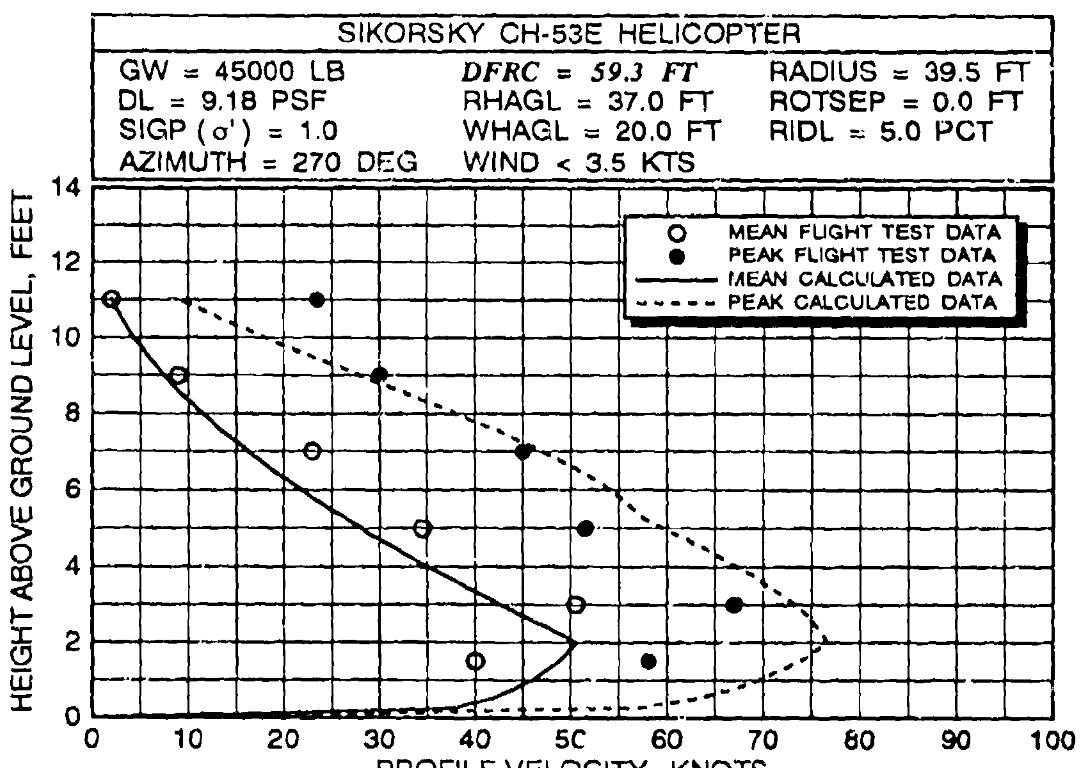
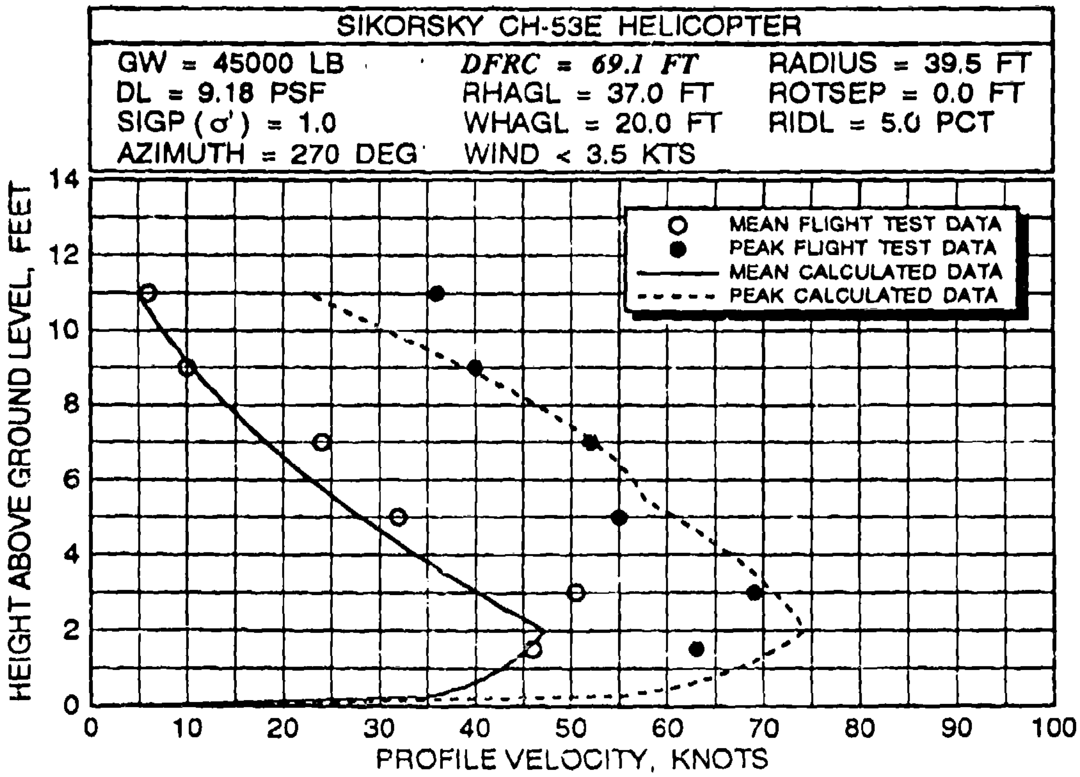


FIGURE B-8 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 37 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



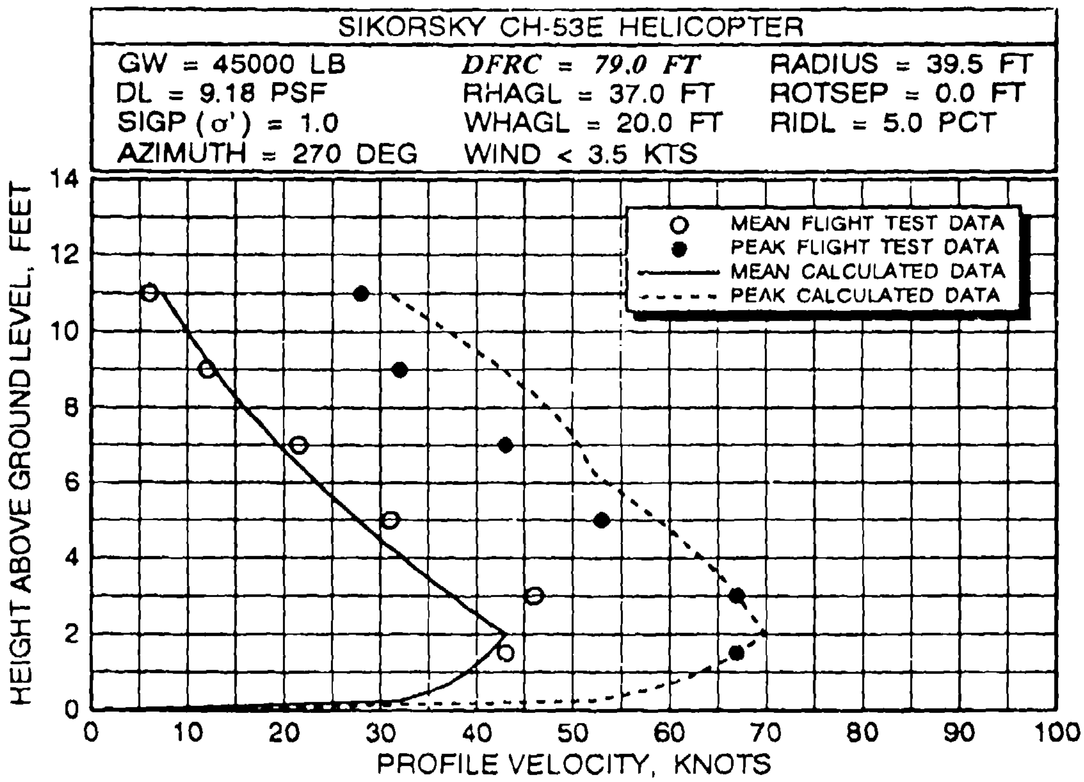
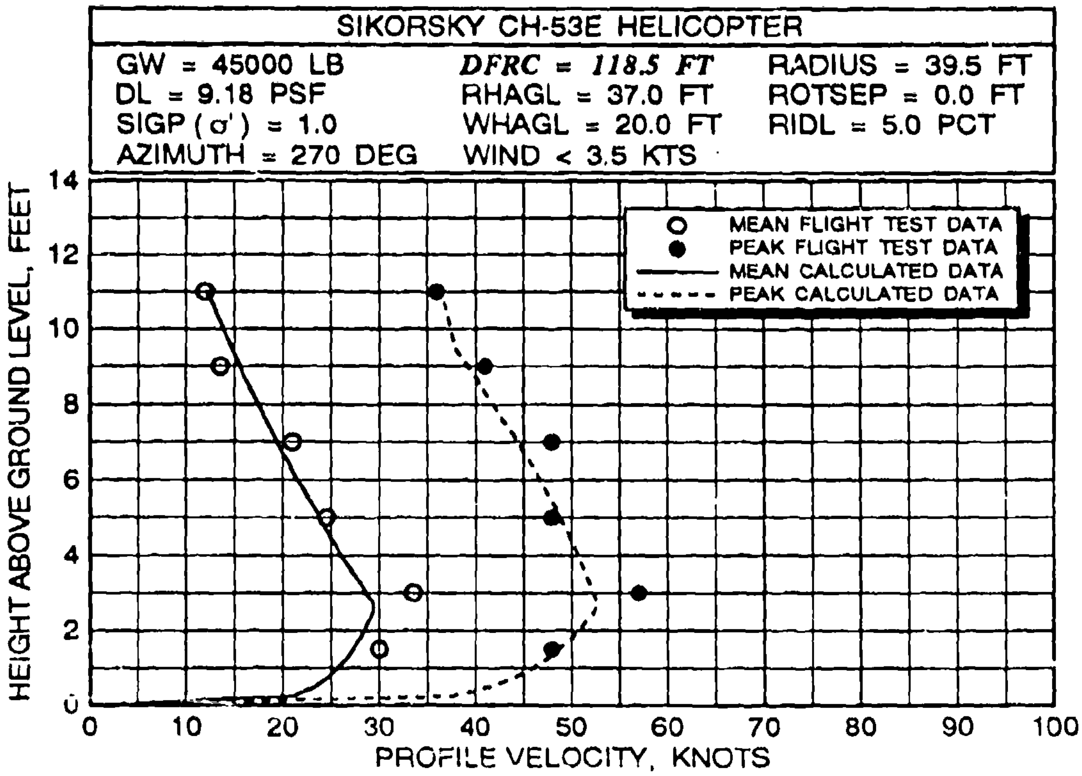


FIGURE B-8 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



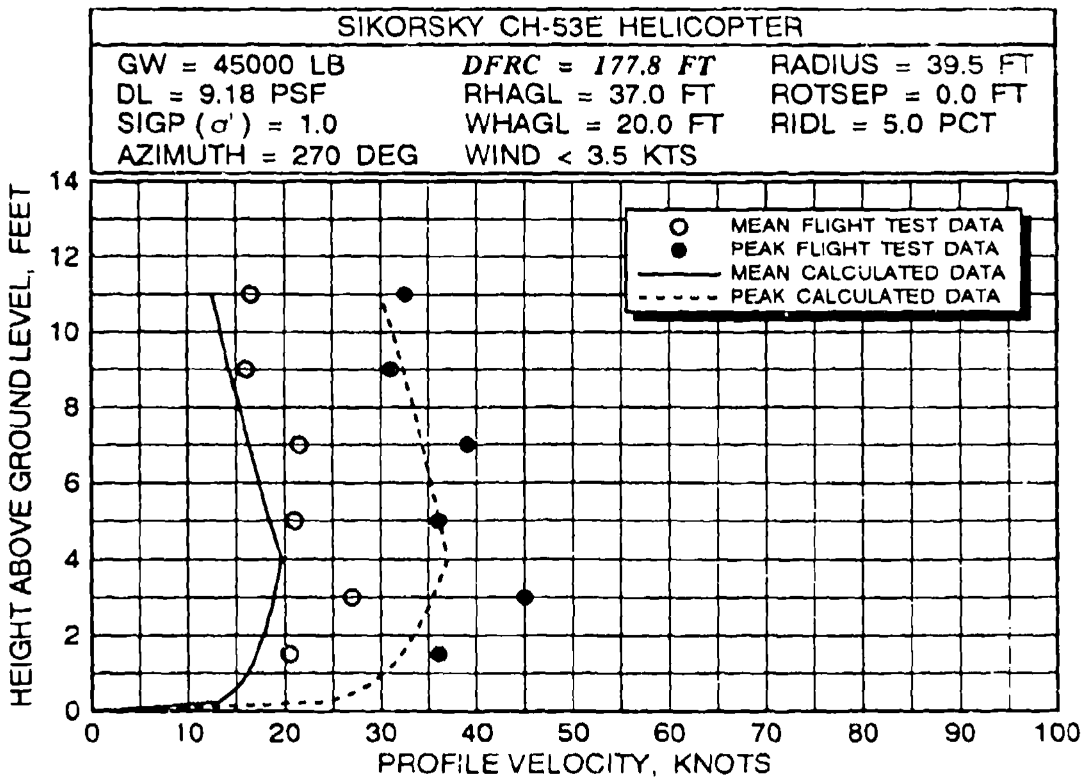
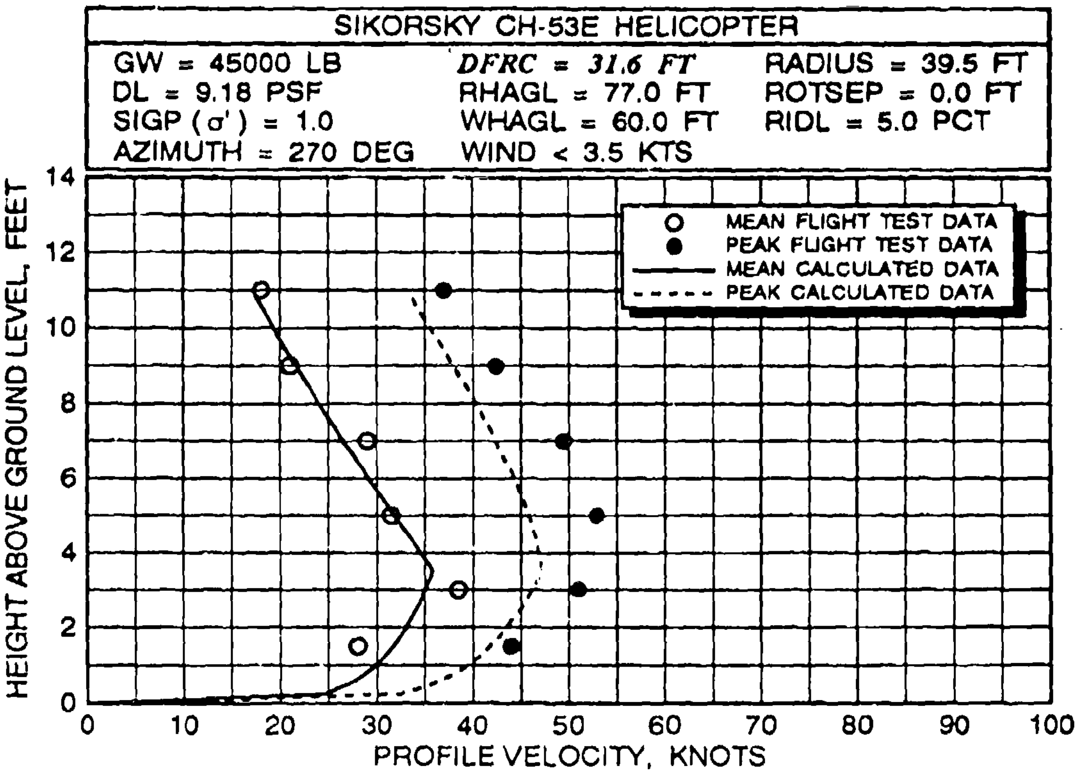


FIGURE B-8 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



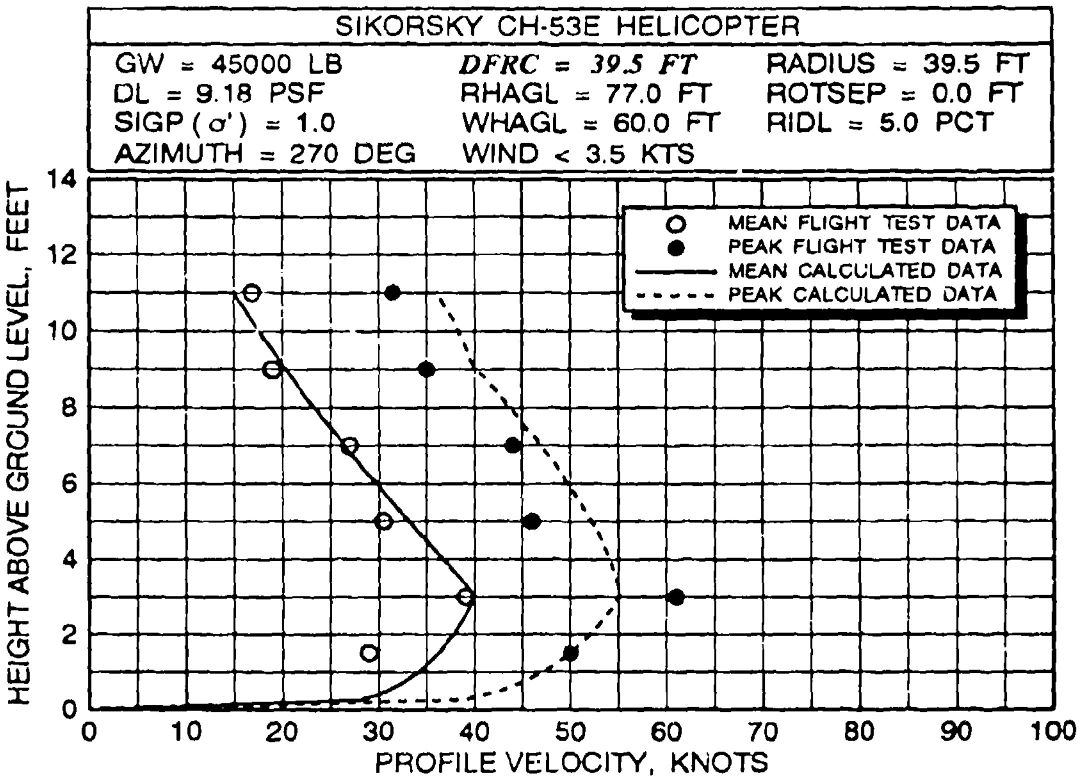
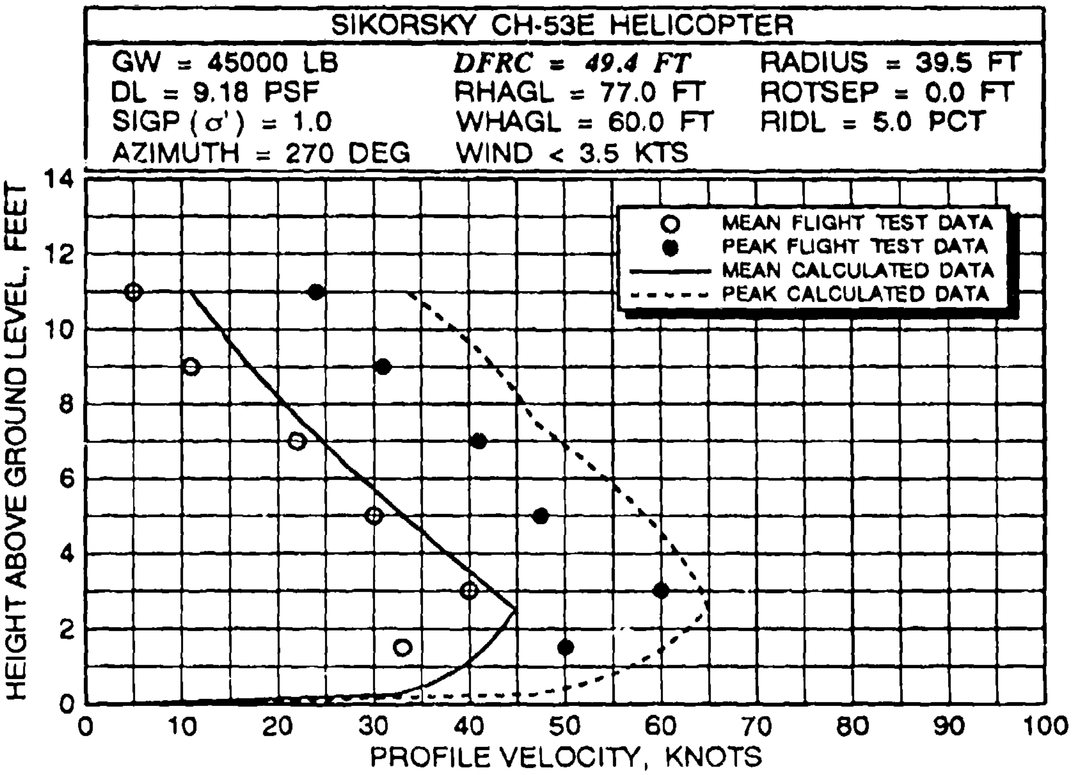


FIGURE B-9 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 45,000 POUNDS



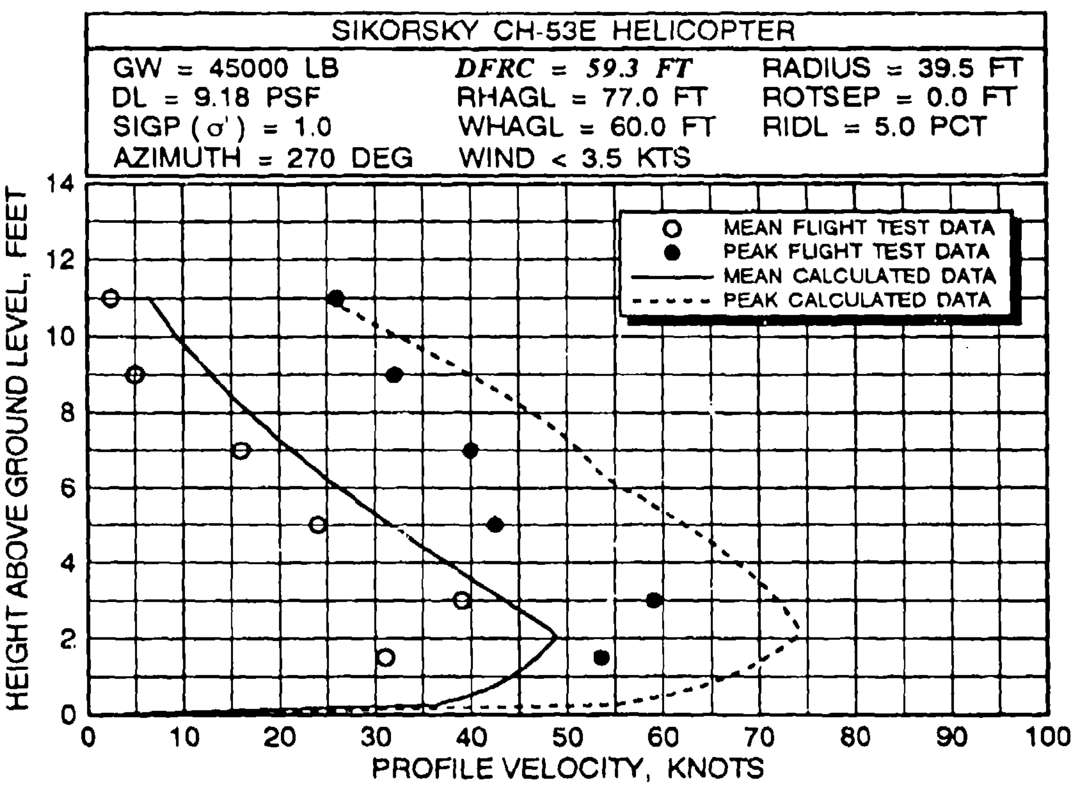
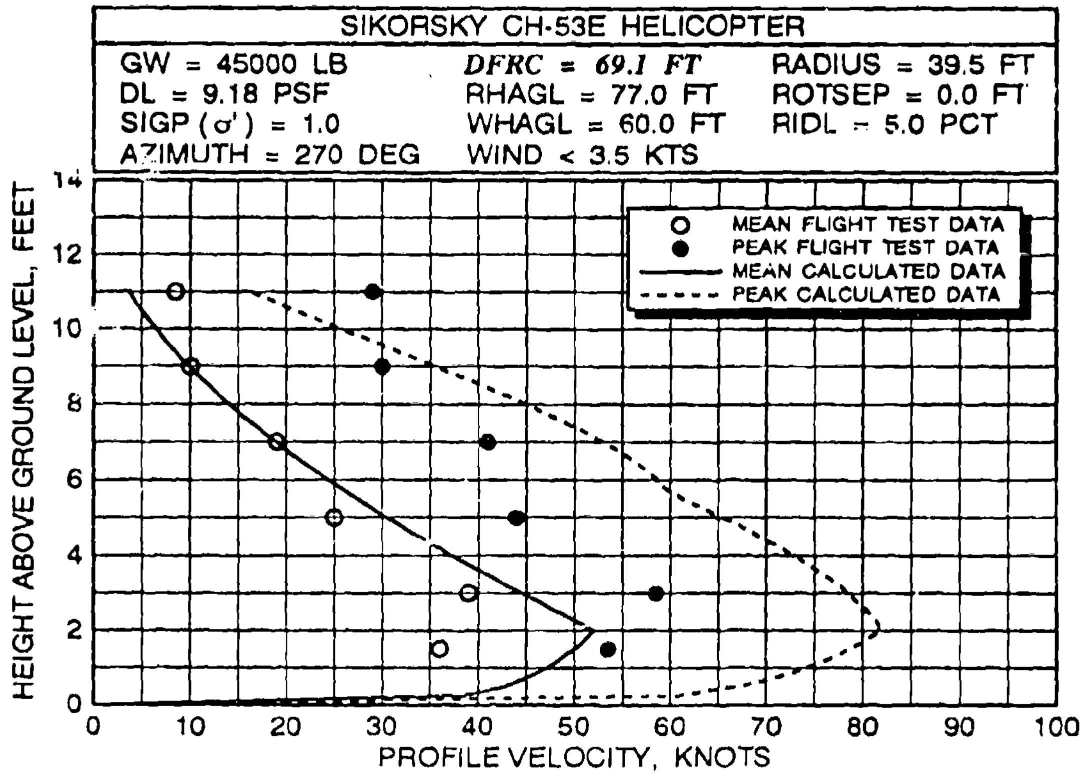


FIGURE B-9 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 77 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



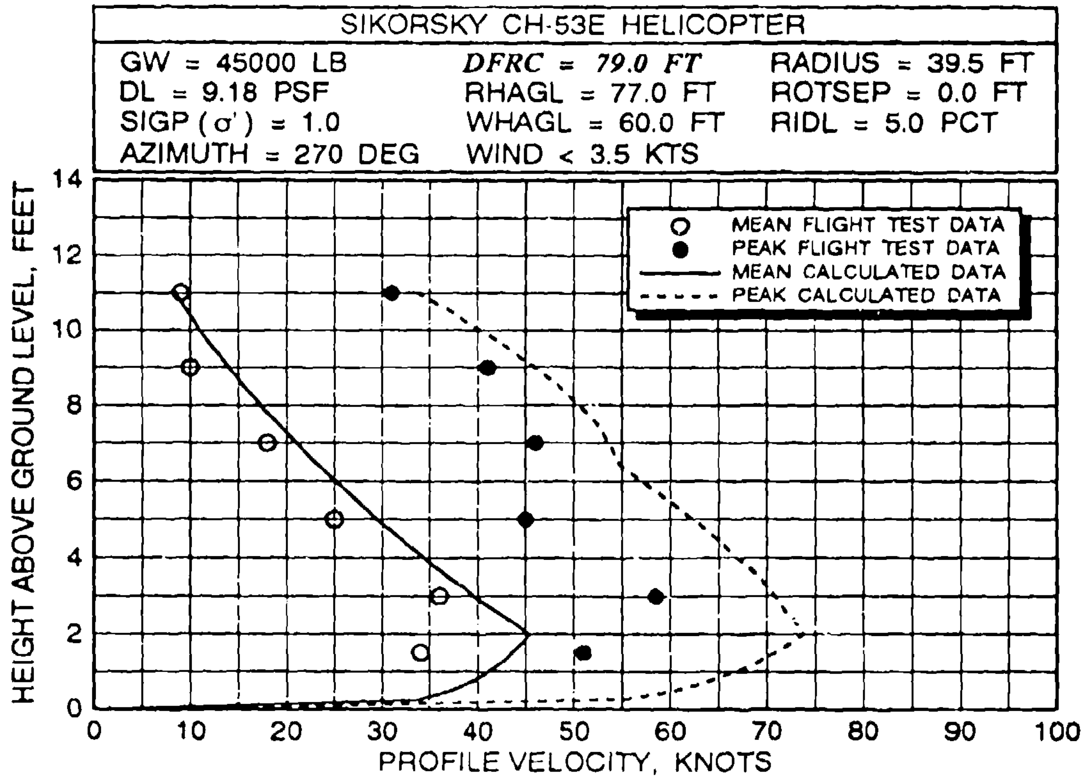


FIGURE B-9 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)

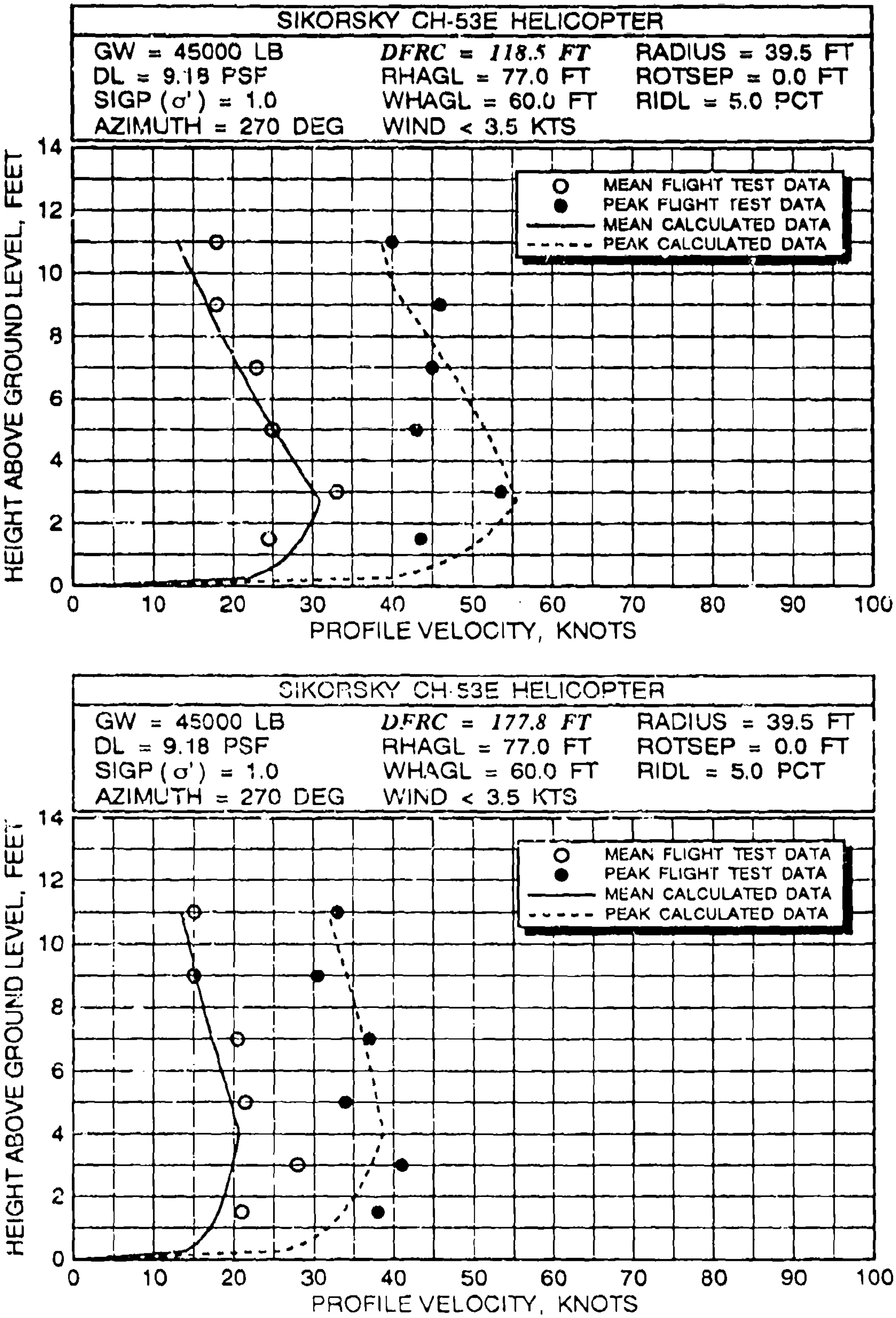
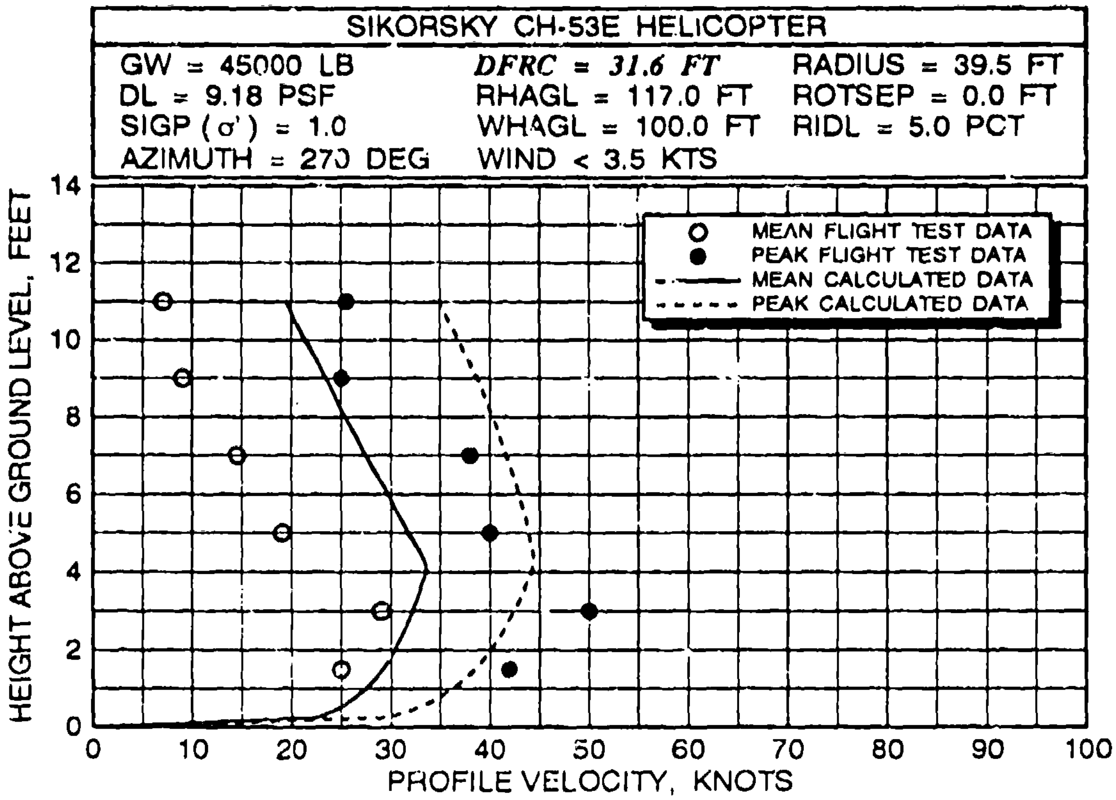


FIGURE B-9 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



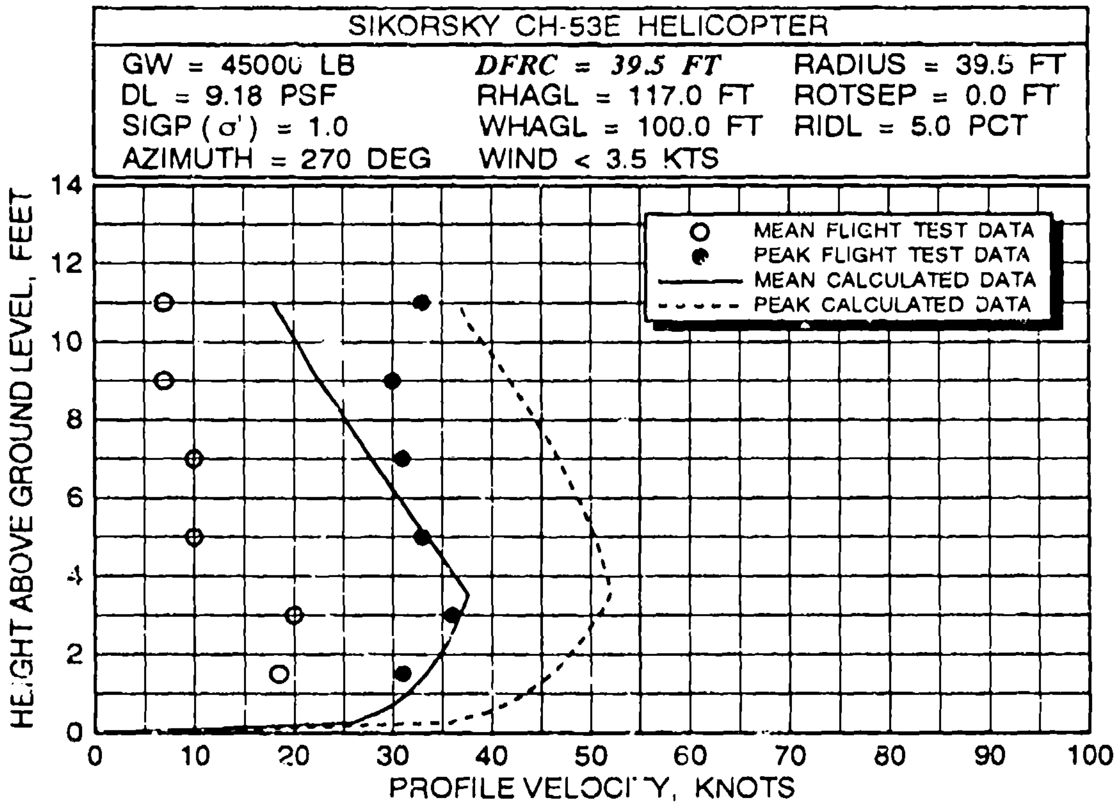
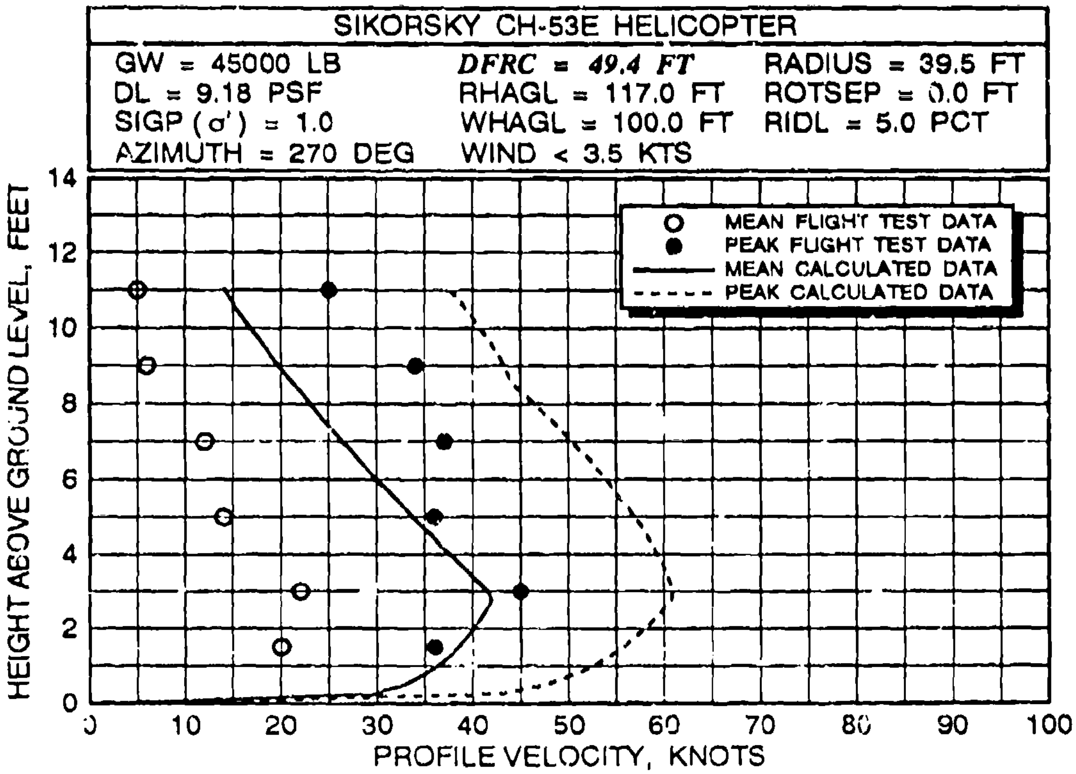


FIGURE B-10 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS



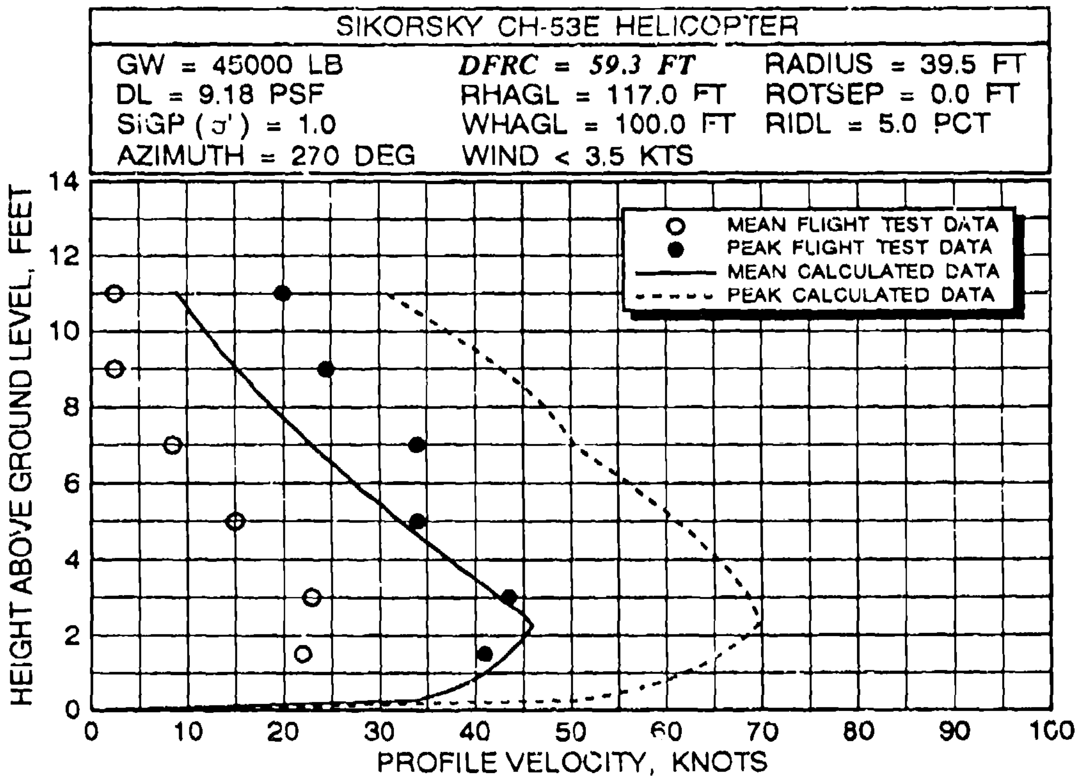
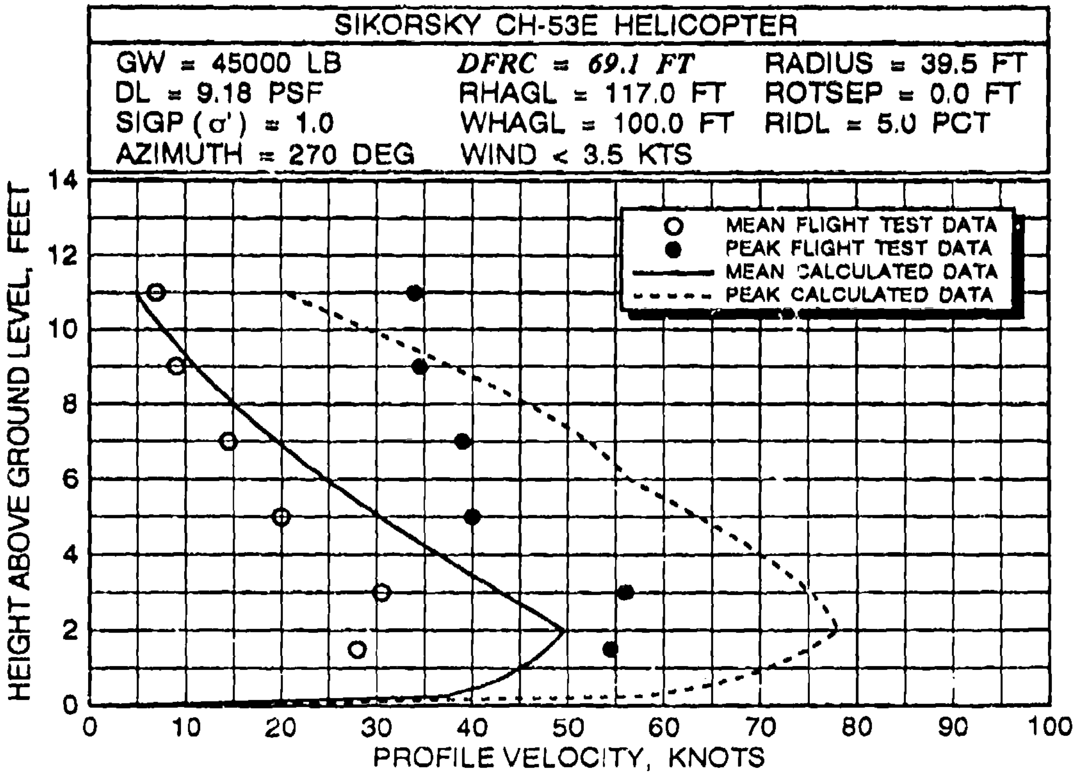


FIGURE B-10 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270-DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



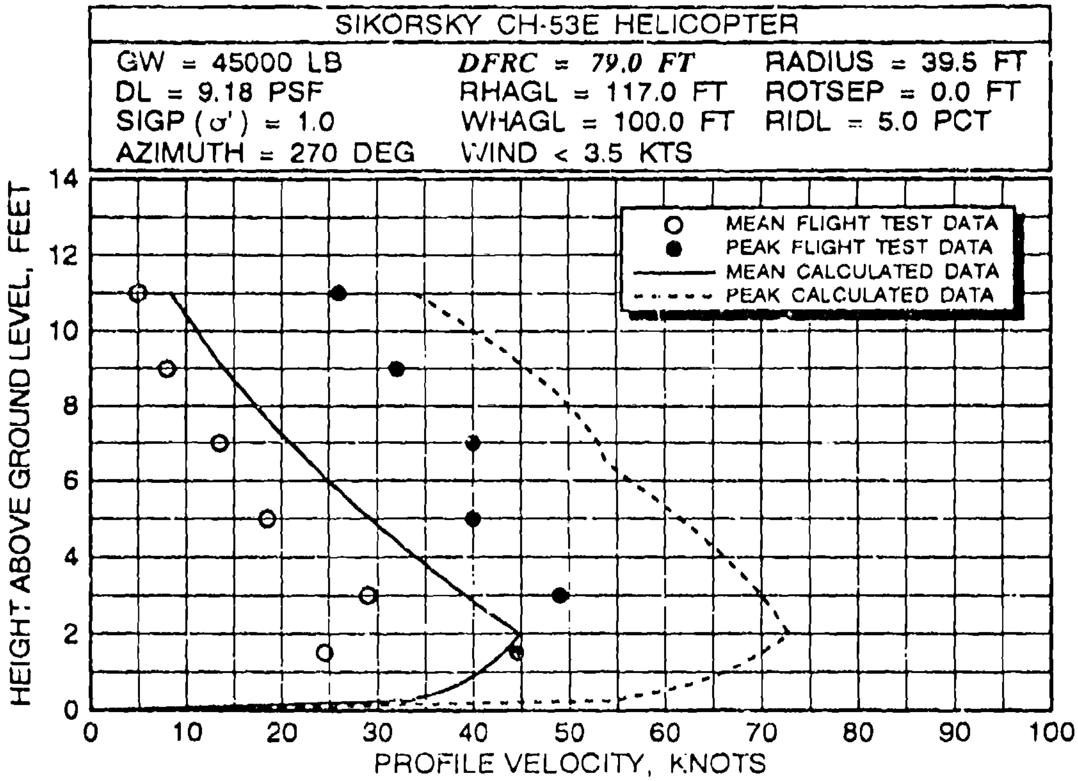
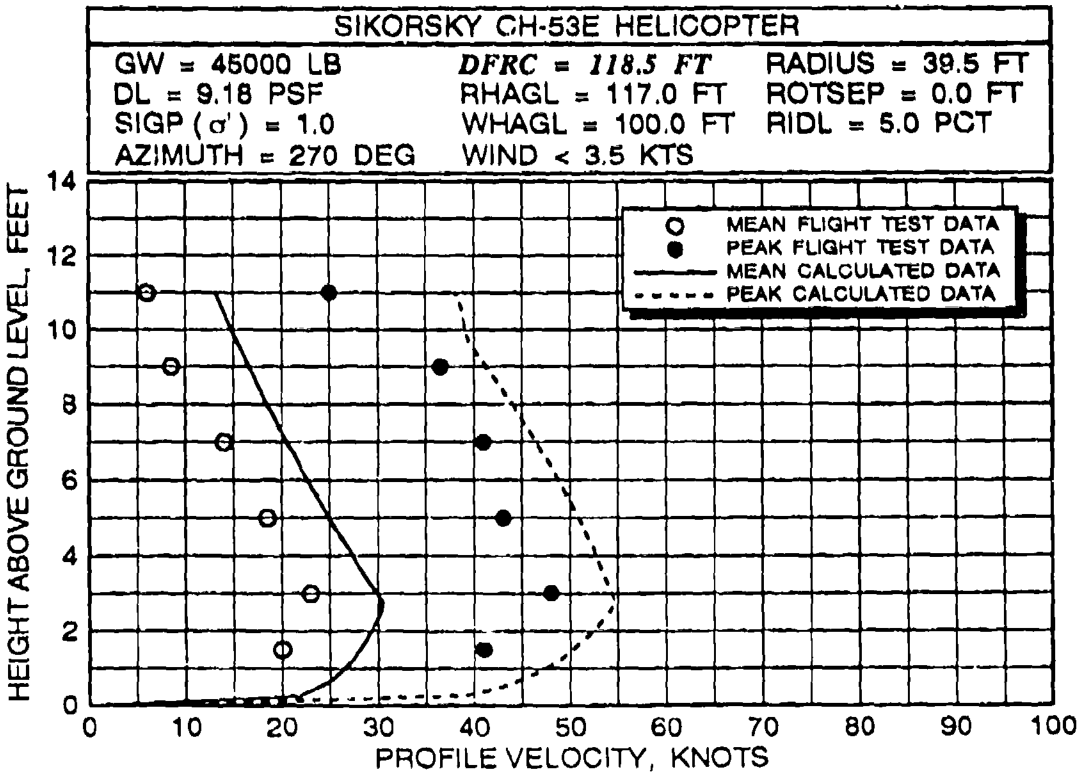


FIGURE B-10 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270- DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)



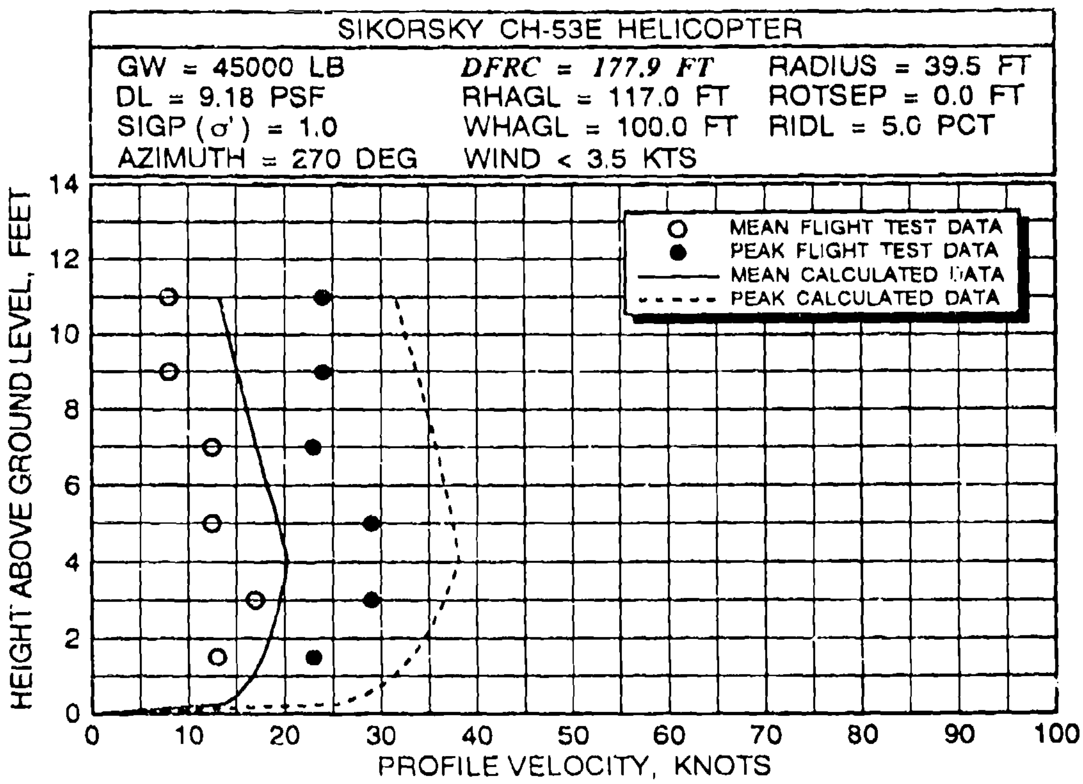


FIGURE B-10 CH-53E MEAN AND PEAK VELOCITY PROFILES FOR EIGHT 270- DEGREE AZIMUTH RADIAL STATIONS AT A ROTOR HEIGHT OF 117 FEET AND A GROSS WEIGHT OF 45,000 POUNDS (continued)

APPENDIX C

A COLLECTION OF REFERENCES PROVIDING INFORMATION OR FURTHER INSIGHT INTO THE ROTORWASH HAZARD ANALYSIS PROBLEM

FULL SCALE AND MODEL DOWNWASH/OUTWASH FLOW FIELD DATA

1. Anon., "VTOL Downwash Impingement Study, Velocity Survey", U.S. Army Transportation Research Command Technical Report No. 60-58, August 1960.

2. Anon., "A Comparison of Downwash and Outflow From a Tilt-Wing Aircraft and a Helicopter", Canadair Report RAG-084-107, February 1971.

3. Ball, LCDR J. C., and D. A. DuFresne, "Shipboard Evaluation of the XV-15 Tilt Rotor Research Aircraft", Naval Air Test Center Technical Report No. RW-54R-82, April 18, 1983.

4. Dyke, R. W., "An Investigation of the Over the Water Aspects of VTOL Airplanes at High Disk Loading", Curtis-Wright Corporation, VTOL Systems Group, Report No. 012-26, December 1963.

5. Fradenburgh, E. A., "Flow Field Measurements for a Hovering Rotor Near the Ground", Fifth Annual Western Forum of the American Helicopter Society, Los Angeles, California, September 1958.

6. Harris, D. J., and R. D. Simpson, "Technical Evaluation of the Rotor Downwash Flow Field of the XV-15 Tilt Rotor Research Aircraft", Naval Air Test Center Technical Report No. SY-14R-83, July 1983.

7. Harris, D. J., and R. D. Simpson, "CH-53E Helicopter Downwash Evaluation. Final Report", Naval Air Test Center Technical Report No. SY-89R-78, August 1, 1978.

8. Harris, D. J., and R. D. Simpson, "Tilt-Wing Vertical and Short Takeoff and Landing Downwash Evaluation. Final Report", Naval Air Test Center Technical Report No. SY-52R-76, April 9, 1976.

9. Harris, D. J., and R. D. Simpson, "Downwash Evaluation Under the U.S. Army Heavy Lift Helicopter Rotor. Final Report", Naval Air Test Center Technical Report No. SY-17R-76, March 16, 1976.

10. Jenkins, B. Z., and A. S. Marks, "Rotor Downwash Velocities About the UH-IH Helicopter - Flight Test Measurements and Theoretical Calculations", Army Missile Research Development and Engineering Laboratory, Redstone Arsenal, Alabama, January 1975.

11. Kuhn, R. E., "An Investigation to Determine Conditions Under Which Downwash from VTOL Aircraft will Start Surface Erosion from Various Types of Terrain", NASA TN D-56, September 1959.

12. Leese, G. W., and J. T. Knight, Jr., "Helicopter Downwash Data", Miscellaneous Paper S-74-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, June 1974.

13. Leese, G. W., "UH-1H Downwash Velocity Measurements", Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, August 1972.

14. Marsh, K. R., "Research on VTOL Water Hover Effects, Including the Effects of Wind and Waves", LTV Aerospace Corporation, Report No. 2-55400/8R-6140, April 1968.

15. Meyerhoff, C., and D. Gordge, "Navy Developmental Test (DT-IIA) of the V-22 Aircraft - Contributory Rotor Downwash Report", Naval Air Test Center Technical Report ACS-CR-90-04, SY71A, Summer 1990.

16. Meyerhoff, C.L.; Lake, Robert; and Peters, Lt. Dean, "H-60 Helicopter Rotor Downwash Wind Velocity Evaluation," Naval Air Warfare Center Report SY-3R-94, Patuxent River, MD, February 1994.

17. Michaelsen, O. E., "A Comparison of Outflows From a Helicopter, Tilt Wing, and Jet Lift Hovering Aircraft", AIAA 8th Annual Meeting and Technical Display, Washington, D.C., AIAA Paper No. 71-992, October 25, 1971.

18. O'Bryan, T. C., "An Experimental Study of the Effect of Downwash From a Twin Propeller VTOL Aircraft on Several Types of Ground Surfaces", NASA TN D-1239, May 1962.

19. O'Bryan, T. C., "An Investigation of the Effect of Downwash from a VTOL Aircraft and a Helicopter in the Ground Environment", NASA TN D-977, October 1961.

20. Patton, W. G., and R. D. Simpson, "Investigation of SH-3/HH-3 Helicopter Downwash Environment", Naval Air Test Center Report ST-197R-71, September 24, 1971.

21. Peterka, J. A., "Wind Tunnel Tests: Dallas Convention Center Expansion", Cermak Peterka Peterson, Inc., Fort Collins, CO, CPP Project 90-0666, June 1991.

22. Skujins, O., "An Experimental Investigation of Rotor Forces and Flow Field in the Vicinity of a Step Ground Plane", West Virginia University, Department of Aerospace Engineering, July 1970.

23. Weiss, R. M., J. G. Morrow, D. Gallagher, M. DiMeo, and S. Erlichman, "Analysis of Heliport Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume I Summary", Federal Aviation Administration, Technical Center, Atlantic City, NJ, Technical Report DOT/FAA/CT-TN87/54-I, October 1988.

24. Weiss, R. M., J. G. Morrow, D. Gallagher, M. DiMeo, and S. Erlichman, "Analysis of Heliport Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume II Wall Street Heliport Data Plots", Federal Aviation Administration, Technical Center, Atlantic City, NJ, Technical Report DOT/FAA/CT-TN87/54-II, May 1989.

25. Weiss, R. M., J. G. Morrow, D. Gallagher, M. DiMeo, and S. Erlichman, "Analysis of Heliport Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume III Indianapolis Downtown Heliport Data Plots", FAA Technical Center, Atlantic City, NJ, Technical Report DOT/FAA/CT-TN87/54-III, October 1989.

26. Weiss, R. M., "Analysis of Heliport Environmental Data; Intracoastal City", Federal Aviation Administration, Technical Center, Atlantic City, NJ, Technical Report DOT/FAA/CT-TN89/43, July 1990.

ROTORWASH AND ROTORWASH HAZARD RELATED ANALYSIS AND PREDICTION TECHNIQUES

1. Ebersol, J. F., "Obscuration by Helicopter-Produced Snow Clouds", Optical Engineering, Vol. 22, No. 1, January/February 1983.

2. Ferguson, S. W., "Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight", Federal Aviation Administration, Washington D.C., Technical Report DOT/FAA/RD-90/16, December 1990.

3. Ferguson, S. W., "Analysis of Rotorwash Effects in Helicopter Mishaps", Federal Aviation Administration, Washington D.C., Technical Report DOT/FAA/RD-90/17, May 1991.

4. Ferguson, S. W., and J. D. Kocurek, "Rotorwash Flow Fields: Flight Test Measurement, Prediction Methodologies, and Operational Issues", Paper Presented at the American Helicopter Society Vertical Lift Aircraft Design Conference, San Francisco, CA, January 17-19, 1990.

5. Ferguson, S. W., and J. D. Kocurek, "Analysis and Recommendation of Separation Requirements for Rotorcraft Operation at Heliports and Airports", Systems Technology, Inc., STI Report TR-1224-1, September 1986.

6. Ferguson, S. W., and J. D. Kocurek, "Rotorwash Computer Model - User's Guide", Federal Aviation Administration, Washington D.C., Technical Report DOT/FAA/RD-90/25, November 1991.

7. George, M., E. Kisielowski, and D. S. Douglas, "Investigation of the Downwash Environment Generated by V/STOL Aircraft Operating in Ground Effect", USAAVLABS Technical Report 68-52, July 1968.

8. George, M., J. Tang, S. Mills, and D. Douglas, "Downwash Environment for the Boeing Model 160 V/STOL Aircraft", Dynasciences Corporation Report DCR-268, January 1968.

9. George, M. M., "Downwash Impingement Design Criteria for VTOL Aircraft", TRECOM Technical Report 64-48, U.S. Army Transportation Research Command, Fort Eustis, VA, August 1964.

10. Glauert, M. B., "The Wall Jet", Journal of Fluid Mechanics, Vol. 1, Part 6, December 1956, pp. 625-643.

11. Hill, W. G., R. G. Jenkins, S. G. Kalemaris, and M. J. Siclari, "Study of VTOL In-Ground-Effect Flow Field Including Temperature Effect", NASA CR-166258, April 1982.

12. Hohler, D. J., "An Analytical Method of Determining General Downwash Flow Field Parameters for V/STOL Aircraft", AFAPL-TR-66-90, November 1966.

13. Kuhn, R. E., "Height of Spray Produced By Vertical Takeoff and Landing (VTOL) Aircraft", David W. Taylor Naval Ship Research and Development Center Report DTNSRDC/ASED-79/04, April 1979.

14. Leese,G. W., "Helicopter Downwash Blast Effects Study", U.S. Army Engineer Waterways Experiment Station TR-3-664, Vicksburg, Mississippi, October 1964.

15. Ludwig, G. R., and W. G. Brady, "Theoretical and Experimental Studies of Impinging Uniform and Nonuniform Jets", TRECOM Technical Report 64-42, U. S. Army Transportation Research Command, Fort Eustis, VA, August 1964.

16. Migdal, D., W. G. Hill, Jr., R. C. Jenkins, and M. J. Siclari, "VTOL in Ground Effect Flows for Closely Spaced Jets", NASA CR 152321, December 1979.

17. Morse, A., and H. Newhouse, "VTOL Downwash Impingement Study Surface Erosion Tests", U.S. Army Transportation Research Command, TREC TR 60-67, Ft. Eustis, VA, October 1960.

18. Nordquist, W. S., "Fog Clearing Using Helicopter Downdrafts: A Numerical Model", Atmospheric Sciences Laboratory, White Sands Missle Range, NM, Technical Report ECOM-5527, December 1973.

19. Plank, V. G., A. A. Spatola, and J. R. Hicks, "Fog Modification By Use of Helicopters", Atmospheric Sciences Laboratory, White Sands Missle Range, NM, Technical Report ECOM-5339 (also Tech. Report AFCRL-70-0593), October 1970.

20. Preston, J.R., "VTOL Downwash/Outwash Operational Effects Model", Paper Presented at the 50th Annual Forum of the American Helicopter Society, Washington DC, May 11-13, 1994.

21. Rogers, S. J., "Evaluation of the Dust Cloud Generated by Helicopter Rotor Downwash", USAAVLABS TR-67-81, March 1968.

22. Rogers, S. J., "Evaluation of the Dust Cloud Generated by Helicopter Rotor Downwash", Proceedings of 7th Annual Conference on Environmental Effects on Aircraft and Propulsion Systems, Sponsored by Institute of Environmental Sciences and the U.S. Naval Air Propulsion Test Center, Mt. Prospect, Il, September 25-27, 1967.

23. Shane, W. P., "Effects of Downwash Upon Man", U.S. Army Aeromedical Research Unit Report No. 68-3, November 1967.

24. Stanzione, K.A. and L.L. Oliver, "Downwash Design Criteria for VTOL Aircraft," Prepared by Praxis Technologies Corporation for the National Aeronautics and Space Administration, Contract NAS2-13395, January 1993.

25. Unitt, Lt. P. J., "A Comprehensive Review of V/STOL Downwash Impingement With Emphasis on Wind Induced Recirculation", Thesis for Air Force Institute of Technology, Report GAM/AE/69-9, March 1969.

26. Velkoff, H.R., "A Comparative Study of Downwash - Outflow Effects of Various VTOL Configurations as a Factor in the Design Selection Process," Advanced Systems Research and Analysis Office, U.S. Army Aviation and Troop Command, NASA Ames Research Center, January 1993.

27. Watts, A., "V/STOL Downwash Impingement Study - Velocity Estimate", Canadair Aerodynamic Memorandum MAA-284-001, January 1969, Revised April 1971.

28. Wernicke, R. K., "Prediction of Tilt Rotor Outwash", AIAA Paper No. 81-0013, AIAA 19th Aerospace Sciences Meeting, January 12-15, 1981.

HELIPORT/VERTIPORT DESIGN AND SAFETY ISSUES

1. Armstrong, J. P., "Evaluation and Control of Dust and Foreign Object Damage (FOD) at the VTOL Forward Operating Site", Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

2. Dzamba, L. D., R. J. Hawley, and R. J. Adams, "Analysis of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites", Federal Aviation Administration, Washington D.C., Technical Report DOT/FAA/RD-90/8, December 1990.

3. Leese, G. W., and J. W. Carr, "Materials Evaluation for Aircraft Blast and Helicopter Downwash Protection", Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, June 1975.

4. McKinley, J. B., "Evaluating Wind Flow Around Buildings on Heliport Placement", DOT/FAA/PM-84/25, October 1984.

5. Negrette, A., "The Unseen Hazard of Rotor Downwash", Rotor & Wing International, Vol. 26, No. 2, February 1992.

6. Nordquist, W. S., and D. H. Dickson, "Helicopter Downwash Applied to Fog Clearing: A Status Summary", Atmospheric Sciences Laboratory, White Sands Missle Range, NM, Technical Report ECOM-5465, October 1972.

7. Peterka, J. A., "Wind Tunnel Tests: Dallas Convention Center Expansion", Cermak Peterka Peterson, Inc., Fort Collins, CO, CPP Project 90-0666, June 1991.

8. Schwartz, C. W., M. W. Witczak, and R. B. Leahy, "Structural Design Guidelines for Heliports", DOT/FAA/PM-84/23, October 1984.

9. Shane, Col. W. P., "Downwash - The Dangers and Defense", Vertiflite, May/June 1972.

10. Surry, D., and G. K. Stone, "A Study of the Effects of the Proposed Rockefeller University Faculty Housing Project on Nearby Helicopter Operations and the Adjacent Building", Boundary Layer Wind Tunnel Laboratory, The University of Western Ontario, London, Ontario, Canada, Report BLWT-SS12-1983, May 1983.

11. Tomita, H., "Effect of Jet-Engine Exhaust on Blast Fences", U.S. Naval Civil Engineering Laboratory, Port Hueneme, CA, Technical Note N-593, May 16, 1964.

12. Tomita, H., "Effects of Jet-Engine Exhaust on Virginia Diabase Concrete Pavement", U.S. Naval Civil Engineering Laboratory, Port Hueneme, CA, Technical Report 089, November 14, 1960.

13. Smith, R.D., "Safe Heliports Through Design and Planning, A Summary of FAA Research and Development", Federal Aviation Administration, Washington D.C., Technical Report DOT/FAA/RD-93/17, February 1994.

LOW SPEED INTERACTIONAL AERODYNAMICS (I.E., GROUND VORTEX)

1. Balch, D. T., "Experimental Study of Main Rotor/Tail Rotor/ Airframe Interaction in Hover", 39th Annual Forum of the American Helicopter Society, St. Louis, Missouri, May 1983.

2. Cimbala, J. M., M. L. Billet, D. P. Gaublomme, and J. C. Oefelein, "Experiments on the Unsteadiness Associated With a Ground Vortex", Journal of Aircraft, Vol. 28, No. 4, April 1991, pp. 261-267.

3. Cimbala, J. M., D. R. Stinebring, A. L. Treaster, M. L. Billet, and M. M. Walters, "Experimental Investigation of a Jet Impinging on a Ground Plane in the Presence of a Cross Flow", Journal of Aircraft, Vol. 25, No. 10, October 1988, pp. 923-931.

4. Curtiss, H. C., Jr., W. F. Putman, and E. J. Hanker, Jr., "Rotor Aerodynamics in Ground Effect at Low Advance Ratios", Department of Mechanical and Aerospace Engineering, Princeton University Report No. 1571-MAE, July 27, 1982.

5. Curtiss, H. C., Jr., Mao Sun, and E. J. Hanker, Jr., "Dynamic Phenomena in Ground Effect", AHS Paper No. A-83-39-76-0000, Presented at the 39th Forum of the American Helicopter Society, May 9-11, 1983.

6. Curtiss, H. C., Jr., M. Sun, W. F. Putman, and E. J. Hanker, Jr., "Rotor Aerodynamics in Ground Effect at Low Advance Ratios", Journal of the American Helicopter Society, Vol. 29, No. 1, January 1984, p. 48.

7. Curtiss, H. C., Jr., W. Erdman, and M. Sun, "Ground Effect Aerodynamics", Presented at the International Conference on Rotorcraft Basic Research, Research Triangle Park, NC, February 19-21, 1985.

8. DuWaldt, F. A., "Wakes of Lifting Propellers (Rotors) in Ground Effect", Cornell Aeronautical Laboratory No. BB-1665-5-3, November 1966.

9. Hanker, E. J., Jr., and R. P. Smith, "Parameters Affecting Helicopter Interactional Aerodynamics in Ground Effect", Journal of the American Helicopter Society, Vol. 30, No. 1, January 1985.

10. Sheridan, P. F., E. J. Hanker, and B. B. Blake, "Investigation of Operational and Design Factors Resulting From Main Rotor and Tail Rotor Interactions", USAAVRADCOM-TR-82-D-40, January 1984.

11. Sheridan, P. F., "Interactional Aerodynamics of the Single Rotor Helicopter Configuration. Volume 1: Final Report", USARTL-TR-78-23A, September 1978.

12. Sun, M., "A Study of Helicopter Rotor Aerodynamics in Ground Effect", Ph.D. Thesis, Princeton Mechanical and Aerodynamics Engineering Department, June 1983.

13. Weisner, W., and G. Kohler, "Tail Rotor Performance in Presence of Main Rotor, Ground, and Winds", Presented at the 29th Annual National Forum of the American Helicopter Society, May 1973.

WAKE VORTEX ENCOUNTERS

1. Anon., "Helicopter Wake Turbulence", Approach, Nov. 1984.

2. Burnham, D. C., and S. A. Teager, "Preliminary Measurements of Helicopter Wake-Vortex Velocity Profiles", DOT-TSC-FA527-PM-85-7, March 1985.

3. Connor, A.B., and T.C. O'Bryon, "A Brief Evaluation of Helicopter Wake as a Potential Operational Hazard to Aircraft," NASA TN D-1227, March 1962.

4. Curtiss, H.C. and Z. Zhou, "The Response of Helicopters to Fixed Wing Aircraft Wake Encounters," Proceedings of Aircraft Wake Vortices Conference - Volume 1 of 2, Washington, D.C., October 29-31, 1991, DOT/FAA/SD-92/1.1, June 1992.

5. Dunham, R.E.; G.T. Holbrook; W.R. Mantay; R.L. Campbell; and R.W. VanGunst, "Flight Test Experience of a Helicopter Encountering an Airplane Trailing Vortex," Presented at the 32nd Forum of the American Helicopter Society, Preprint 1063, May 1976.

6. Johnson, W. A., and T. T. Myers, "A Model for Human Pilot Behavior During Wake Vortex Encounter Upsets", FAA-RD-76-8, April 1976.

7. Johnson, W. A., and G. L. Teper, "Analysis of Vortex Wake Encounter Upsets", NASA CR-127491, August 1974.

8. Mantay, W. R., G. T. Holbrook, R. L. Campbell, and R. L. Tomaine, "Helicopter Response to an Airplane's Trailing Vortex", Journal of Aircraft, Vol. 14, No. 4, April 1977, pp. 357-363.

9. Sammonds, R. L., and G. W. Stinnett, Jr., "Hazard Criteria for Wake Vortex Encounters", NASA TM X-62,473, August 1975.

10. Tymczyszyn, J. J., K. J. Biehl, and S. A. Teager, "Flight Test Investigation of the Wake Vortices Generated By Helicopters", Proceedings of the Aircraft Wake Vortices Conference - Volume 1 of 2, Washington D.C., October 29-31, 1991, DOT/FAA/SD-92/1.1, June 1992.

OTHER REFERENCES

1. Anon., "Full-Scale Tests of Grumman Design 698-411 Tilt-Nacelle V/STOL Model at the NASA-Ames Research Center", Grumman Report PDR 698-33, December 1981.

2. Childs, R. E., and D. Dixon, "Unsteady Three-Dimensional Simulations of a VTOL Upwash Fountain", Paper Presented at AIAA 24th Aerospace Sciences Meeting, January 6-9, 1986.

3. Donaldson, C. D., and R. S. Snedeker, "A Study of Free Jet Impingement. Part 1. Mean Properties of Free and Impinging Jets", Journal of Fluid Mechanics, Vol. 45, Part 2, 1971, pp. 281- 319.

4. Heyson, H. H., "Some Wake Related Operation Limitations of Rotorcraft", NASA TM-81920, December 1980.

5. Heyson, H. H., "Theoretical Study of the Effect of Ground Proximity on the Induced Efficiency of Helicopter Rotors", NASA TM X-71951, May 3, 1977.

6. Hill, W. G., and R. C. Jenkins, "Effect of Nozzle Spacing on Ground Interference Forces for a Two-Jet V/STOL Aircraft", Journal of Aircraft, Vol. 17, No. 9, September 1980, pp. 684-689.

7. Hill, W. G., Jr., and R. C. Jenkins, "Experimental Investigation of Multiple Jet Impingement Flows Applicable to VTOL Aircraft in Ground Effect", Grumman Research Department Memorandum RM-605, November 1975.

8. Jenkins, R. A., and W. G. Hill, Jr., "Investigation of VTOL Upwash Flows Formed by Two Impinging Jets", Grumman Research Department RE-548, November 1977.

9. Kohlman, D. L., Introduction to V/STOL Airplanes, Iowa State University Press, 1981.

10. Peck, R.E., "Aerodynamics of a Round Jet in a Counterflowing Wind", Journal of Aircraft, Vol. 18, No. 1, January 1981, pp. 61-62.

11. Platzer, M. F., and R. J. Margason, "Prediction Methods for Jet V/STOL Propulsion Aerodynamics", Journal of Aircraft, Vol. 15, No. 2, February 1978, pp. 69-77.

12. Siclari, M. J., W. G. Hill, Jr., R. D. Jenkins, and D. Migdal, "VTOL In-Ground Effect Flows for Closely Spaced Jets", AIAA Paper No. 80-1880, AIAA Aircraft Systems Meeting, August 4-6, 1980.

13. Siclari, M. J., W. G. Hill, Jr., and R. C. Jenkins, "Stagnation Line and Upwash Formation of Two Impinging Jets", AIAA Journal, Vol. 19, No. 10, October 1981, pp. 1286-1293.

14. Siclari, M. J., D. Migdal, and J. L. Palcza, "Development of Theoretical Models for Jet-Induced Effects on V/STOL Aircraft", Journal of Aircraft, Vol. 13, No. 12, December 1976, pp. 936- 944.

15. White, F., and B. B. Blake, "Improved Method of Predicting Helicopter Control Response and Gust Sensitivity". Presented at the 35th Annual National Forum of the American Helicopter Society, Washington, D.C., May 1979.

16. Wohllebe, F. A., and M. J. Siclari, "Fountain and Upwash Flowfields of Multijet Arrangements", Journal of Aircraft, Vol. 15, No. 8, August 1978, pp. 468-473.

APPENDIX D
USER'S GUIDE

D.1 ROTWASH PROGRAM USER'S GUIDE

The style of the ROTWASH user's guide presented in this appendix is primarily narrative. This format is designed to guide the reader through a step-by-step explanation on the use of each program software option. Example output from each option is presented exactly as it would be viewed by the user on a video terminal for reference purposes. Examples of user keyboard input are presented in **<BOLD>** text as an aid to the reader.

D.1.1 GETTING STARTED

The ROTWASH program is executed by typing the program name at the DOS system prompt:

<ROTWASH>

To avoid possible system errors, the user should execute the program from the directory containing the program (or set the appropriate DOS system PATH command). The user should also be aware that menu and data printouts to the screen will not work correctly unless the **device=C:\DOS\ANSI.SYS** command is contained in the CONFIG.SYS file.

The ROTWASH program responds with the screen output presented in figure D-1. This output is the ROTWASH program header page.

```
                    ROTWASH PROGRAM

           ROTORCRAFT DOWNWASH HAZARD ANALYSIS

             EMA / SYSTEMS CONTROL TECHNOLOGY
         *** PROGRAM VERSION 2.1, APRIL 1993 ***




                     PRESS <RETURN>
```

FIGURE D-1 ROTWASH PROGRAM HEADER OUTPUT

After typing the carriage return **<RETURN>** or **<ENTER>** key, the user is asked to specify the path for ROTWASH program input and output (I/O). The only option for input at the present time is the terminal keyboard. This is specified by typing **<CON>** for console or keyboard (lower case inputs such as **<con>** are also permitted). Program output may be sent to one of three different locations. These output locations are:

<u>OUTPUT OPTION</u>	<u>TYPING COMMAND</u>
Screen	**<CON>**
Printer	**<PRN>**
Disk Plotting File	**<PLT>**

An example of the video screen output for this program menu is presented in figure D-2 where the **<CON>** option has been chosen for both input and output.

```
          I/O CAN BE DIRECTED TO FILES OR DEVICES

                VALID DEVICES ARE AS FOLLOWS:

                    <CON>  ==>  CONSOLE
                    <PRN>  ==>  PRINTER
                    <PLT>  ==>  GRAPHICS FILE


            ENTER INPUT FILE/DEV NAME  ==> CON
            ENTER OUTPUT FILE/DEV NAME ==> CON
```

FIGURE D-2 ROTWASH PROGRAM INPUT/OUTPUT CONTROL MENU

D.1.2 INPUT DATA REQUIREMENTS

Rotorcraft characteristics and atmospheric conditions that are common to all program options are input to the program using the master input data menu. Four basic configurations of rotor or propeller driven aircraft can be represented using this menu. These configurations include single and tandem rotor helicopters, tiltrotors, and twin-propeller tiltwings. This menu is presented to the user as shown in figure D-3 after the I/O menu is completed. The default values provided in the menu define the Bell XV-15 tiltrotor. Design data describing most other modern types of rotorcraft are provided in appendix A.

```
                    ROTWASH USER INPUT DATA MENU

 CODE               PARAMETER                        VALUE     UNITS

   A       NUMBER OF ROTORS (1 OR 2)                   2        -ND-
   B       HUB TO HUB ROTOR SEPARATION               32.2        FT
   C       ROTOR RADIUS                              12.5        FT
   D       GROSS WEIGHT                           13000.0        LB
   E       FUSELAGE DOWNLOAD FACTOR                  13.0       PCT
   F       ROTOR HEIGHT ABOVE GROUND                 37.0        FT
   G       SHAFT TILT ANGLE (<20 DEG)                  .0       DEG
   H       AIR DENSITY RATIO                       1.0000        ND
   I       AMBIENT WIND (-10 TO 10 KT)                 .0        KT


  ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==> D

                                   GROSS WEIGHT =  13000.0

  ENTER NEW VALUE OR <RETURN> TO LEAVE AS IS     ==> 13500.0
```

FIGURE D-3 MASTER INPUT DATA MENU

The first input data variable listed on the menu is the number of rotors (or propellers). This value will always be two except for single main rotor helicopters (the tail rotor is not considered a lifting rotor by the ROTWASH analysis). The next four menu variables define the design details of the rotorcraft configuration. These variables are the hub-to-hub separation distance for twin-rotor configurations (in feet), rotor radius (feet), rotorcraft gross weight (pounds), and the rotor-on-wing download factor (percent). The download factor represents the percent increase in hover rotor thrust required to overcome the rotor-induced vertical drag force on the airframe (where thrust is initially assumed to equal gross weight). For most helicopters, this value is less than 5 percent. Download on tiltrotors can generally be expected to vary from 8 to 13 percent because of the large wing area under the rotor.

The next two input data variables define the position of the rotor with respect to the ground plane. The rotor height (feet) is defined as the distance from the ground surface to the plane of the rotor. The mast angle (degrees) is defined as the tilt of the rotor plane with respect to the ground plane. The mast angle is defined as 0 degrees when the plane of the rotor is parallel to the ground plane and a positive angle is a forward tilt of the mast (which is presently limited in the program to 20 degrees). Since most rotorcraft hover with the plane of the rotor parallel to the ground, it is recommended that caution be exercised when non-zero values are used for mast angle. Non-zero uses of the variable might involve hover investigations for tiltwing aircraft

with the wing tilted forward (where a pitch fan provides the trim pitching moment). Also, limited rotorwash investigations for takeoff and landing maneuvers might be attempted if approximate rotor thrust levels are known for various segments of the maneuvers.

The last two input data variables on the menu define the atmospheric conditions. The air density ratio is defined as the ratio of the desired air density to the sea level standard air density (0.0023769 slugs/feet^3). Ambient wind speed (knots) is specified by the user up to a limit of 10 knots. Values greater than this limit are believed to invalidate several empirically determined mathematical modeling assumptions (limits are discussed in sections 2 and 3 of Volume I of this report).

The mechanics of using the menu are quite simple. The user types in the code value for the variable to be changed and then types **<RETURN>**. The next prompt asks for the new parameter value. After this value and another **<RETURN>** are typed, the menu is rewritten to the screen with the new value. This simple process is continued until the user specifies each variable to its desired value. At this point, the **<RETURN>** key is typed by itself. This menu can also be reached from most of the other menus in the program whenever the user decides that the basic configuration needs to be modified. This is accomplished by typing **<N>** for NEW CASE when the option is offered.

D.1.3 ANALYSIS PROBLEM DEFINITION

After the master input data menu is completed, the user specifies the desired type of analysis option. Figure D-4 presents the program logic/comment menu and the associated list of default values. This menu has two groupings of parameters which need to be specified.

The first parameter on the menu specifies the choice of either the velocity calculation analysis option or the hazard analysis option. The velocity analysis option is the default option on the menu. This option is otherwise chosen by typing the code **<A>**, then **<RETURN>**, then **<V>**, and finally **<RETURN>**. The same process is used to specify the hazard analysis option except that **<H>** is substituted for **<V>** as the parameter value. The second menu parameter provides an interactive toggle switch for the option which writes out data files to disk for graphics programs. (This parameter is also offered as an option on the initial ROTWASH menu by typing **<PLT>**). There is no limit to the number of times this switch can be toggled. As long as the parameter has a **<Y>** or "yes" value, the user must specify output filenames before data files are written to disk. The user is not allowed to write over files previously written to disk by specification of the same filename twice.

```
            ROTWASH PROGRAM LOGIC/COMMENT MENU

CODE              PARAMETER                      VALUE

  A      ANALYSIS TYPE,     <V> OR <H>             V
  B      GRAPHICS FILE,     <Y> OR <N>             N


     USER INPUT COMMENTS (FOR "PRN" AND "PLT" OUTPUT)

       <---                50 SPACES                   --->
  C    XV-15 CHARACTERISTICS ARE USED AS INPUT DATA
  D    GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS

ENTER CODE FOR DATA INPUT OR <RETURN> TO CONTINUE ==>
```

FIGURE D-4 ROTWASH PROGRAM LOGIC/COMMENT MENU

The last two lines in the menu are used to specify user comments in all data files that are written to disk. These comments are also written out as header information on screen output sent directly to the printer. Both of the comment lines can be changed at any time during program execution. The only restriction is that the character strings on both lines be less than or equal to 50 characters. The arrowhead symbols above the comment lines in the menu define a 50-space line width.

If the velocity analysis option is specified, the user is then required to choose one of the four analysis options presented in figure D-5. Velocity analysis options reached through this menu are the:

1. simple wall jet (for both single and twin-rotor configurations),
2. interaction plane (twin-rotor only),
3. ground vortex (single rotor only), and
4. disk edge vortex (single rotor only).

```
SELECT TYPE OF FLOW TO BE ESTIMATED

WALL JET PROFILE,                 TYPE <W>
INTERACTION PLANE PROFILE,        TYPE <J>
GROUND VORTEX,                    TYPE <G>
DISK VORTEX,                      TYPE <D>
TO EXIT PROGRAM,                  TYPE <X>

ENTER DATA ENTRY CODE   ==> W
```

FIGURE D-5 VELOCITY ANALYSIS OPTION MENU

Each of these four options is described with flowfield characteristics sketches in subsequent sections. For technical details and discussion on practical limitations of these options, the user is referred to Sections 2 and 3 of Volume I of this report. The choice of one of these menu options is made by typing the appropriate code and **<RETURN>**. If one of the five allowable characters is not chosen, the menu will reappear and the user will be forced to choose an acceptable option.

If the hazard analysis option is specified, the user is presented with the figure D-6 menu. This menu allows the user to choose either:

1. human overturning force/moment analysis, or
2. particulate cloud analysis.

Both of these analyses can be applied to either single or twin-rotor configurations. The mechanics of this menu operate exactly like those of the velocity analysis option menu.

D.1.4 THE WALL JET OPTION

Rotorwash velocity profiles are calculated for single main rotor helicopter configurations using the wall jet option. Velocity profiles along the 0- and 180-degree azimuths for tandem helicopters and the 90- and 270-degree azimuths for twin-rotor side-by-side configurations are also calculated using this option (90 degrees is out the right wing on a tiltrotor and 0 degrees is along the centerline of the fuselage for tandem rotor helicopters). Figure D-7 provides a three-dimensional view of

```
                  SELECT TYPE OF HAZARD

      OVERTURNING FORCE/MOMENT,      TYPE <M>
      PARTICULATE CLOUDS,            TYPE <C>
      TO EXIT PROGRAM,               TYPE <X>

               ENTER HAZARD CODE ==> M
```

FIGURE D-6 HAZARD ANALYSIS OPTION MENU

the rotorwash flowfields associated with both rotor configurations. Figure D-8 provides a cross-sectional view of the nondimensionalized ROTWASH wall jet velocity profile model. The program menu associated with the use of this option is presented in figure D-9.

The velocity profile status menu provides the user the option to specify four parameters before proceeding with detailed calculations. The horizontal distance on the ground from the <u>center</u> of the rotor to where the velocity profile should be calculated is the first parameter specified on the menu. Figure D-10 is provided to illustrate this geometry graphically using the Bell XV-15, which is the more complex example (flight test data results associated with this figure are documented in reference D-3). To specify the profile station position for the wall jet with the XV-15 (270-degree radial), the user would measure the distance from the aircraft centerline (DFAC) and subtract 16.1 feet (the distance from the centerline to the center of the rotor). The remaining two position-related parameters to be specified are the vertical calculation increment and the maximum height above ground level (AGL) to which the profile should be calculated. The default values for these three parameters are 50 feet, 1 foot, and 10 feet, respectively.

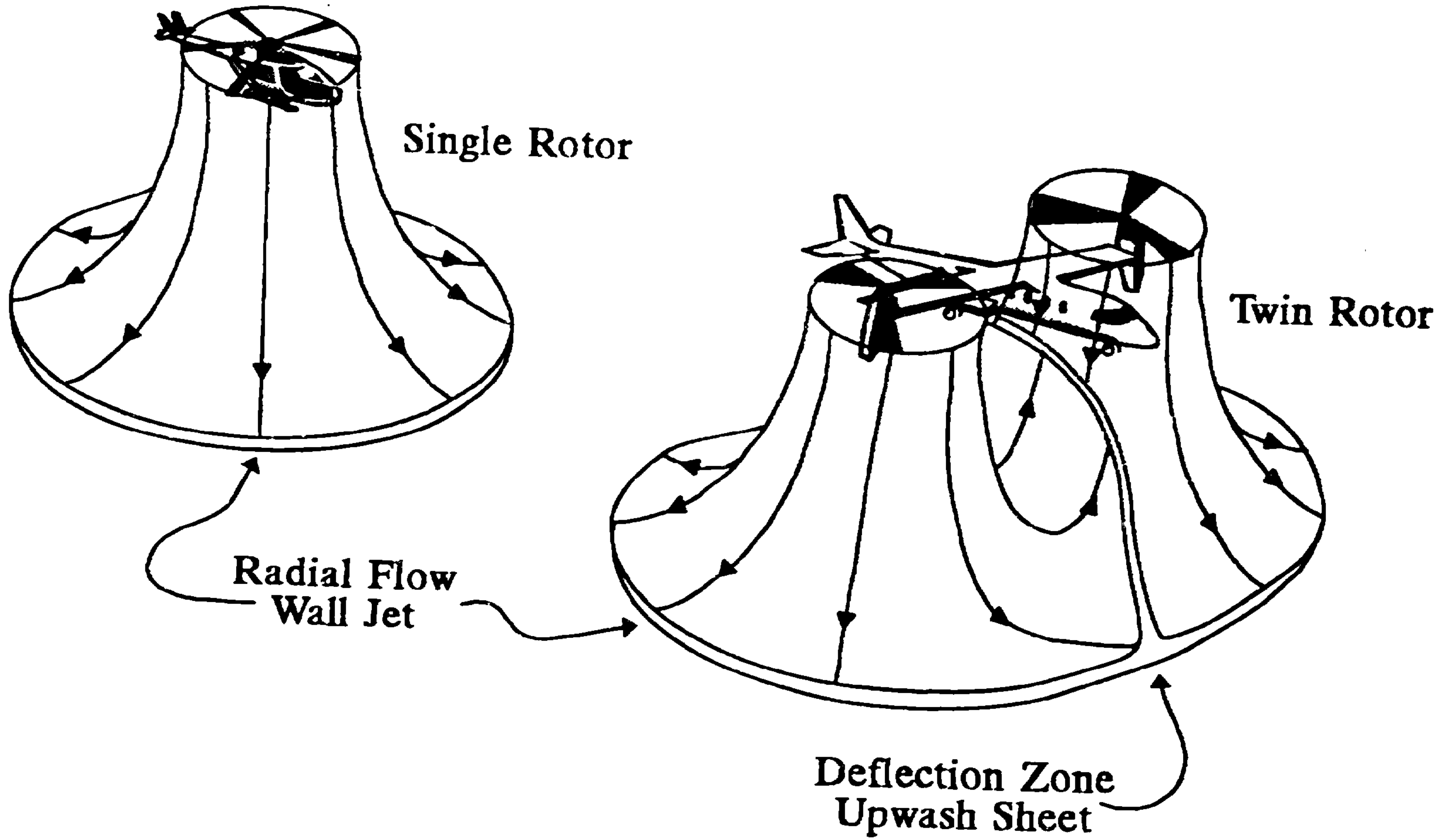


FIGURE D-7 ROTORWASH FLOW FIELDS OF SINGLE- AND TWIN-ROTOR CONFIGURATIONS OPERATING IN CLOSE PROXIMITY TO THE GROUND

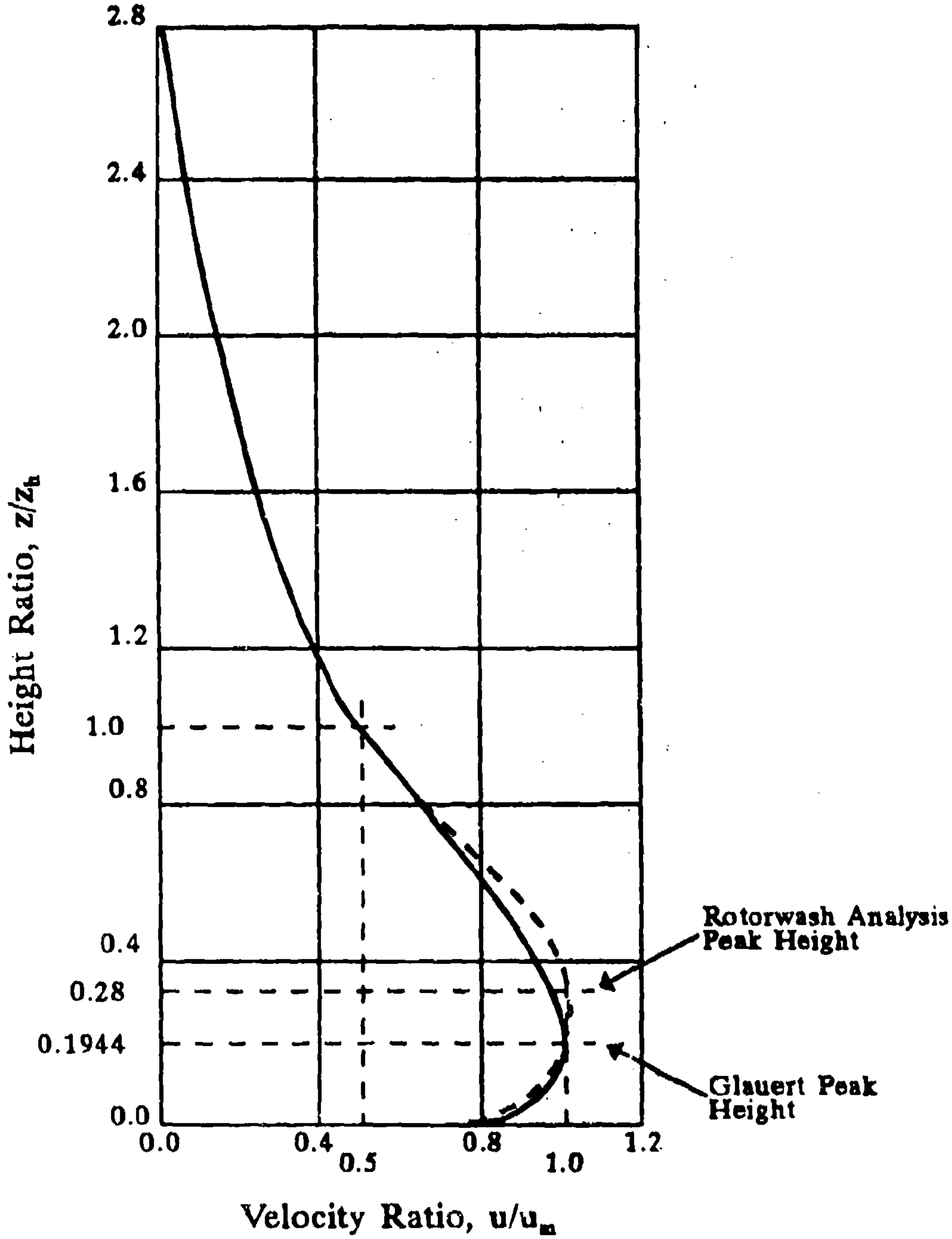


FIGURE D-8 NON-DIMENSIONAL WALL JET VERTICAL VELOCITY PROFILE

	VELOCITY PROFILE STATUS MENU		
CODE	PARAMETER	VALUE	UNITS
A	PROFILE STATION POSITION	50.00	FT
B	VERTICAL INCREMENT	1.00	FT
C	MAXIMUM PROFILE HEIGHT	10.00	FT
D	MINIMUM BOUNDARY LAYER HEIGHT	1.50	FT
E	DATA OUTPUT FILENAME	DFRC.PTS	
ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==>			

FIGURE D-9 VELOCITY PROFILE STATUS MENU

An option is also provided to allow the user to specify a minimum boundary layer height based on flight test data. The default value of 1.5 feet for this value will insure that the peak velocity on the profile is always equal to or greater than 1.5 feet (at very close positions to the rotor, the ROTWASH methodology often calculates an unrealistically thin boundary layer if a minimum limit is not specified). Each of the four parameters is input by typing the appropriate code, **<RETURN>**, the new input data value, and **<RETURN>** to end the sequence. The last parameter on the menu is the filename for data that is written to disk if the graphics file toggle switch is set to **<Y>**.

The wall jet velocity profile, calculated by the program using default inputs, is presented in figure D-11 when the **<RETURN>** key is typed by itself. Output from the analysis describes the shape of both the mean and peak velocity profiles; an example is presented in figure D-12 correlated with Bell XV-15 flight test data (this particular example correlates to a rotor height of 37.5 feet and a DFAC value of 66.1 feet on figure D-10).

The output format provides velocity profile data in units of either feet per second, knots, or pounds per square foot (also referred to as dynamic pressure).

If the specified increment in vertical height is small or the maximum calculated height is large, the quantity of data to be output to the screen may exceed the 10-line limit for 1 screen frame. When this situation occurs, the typing of **<C>** at the

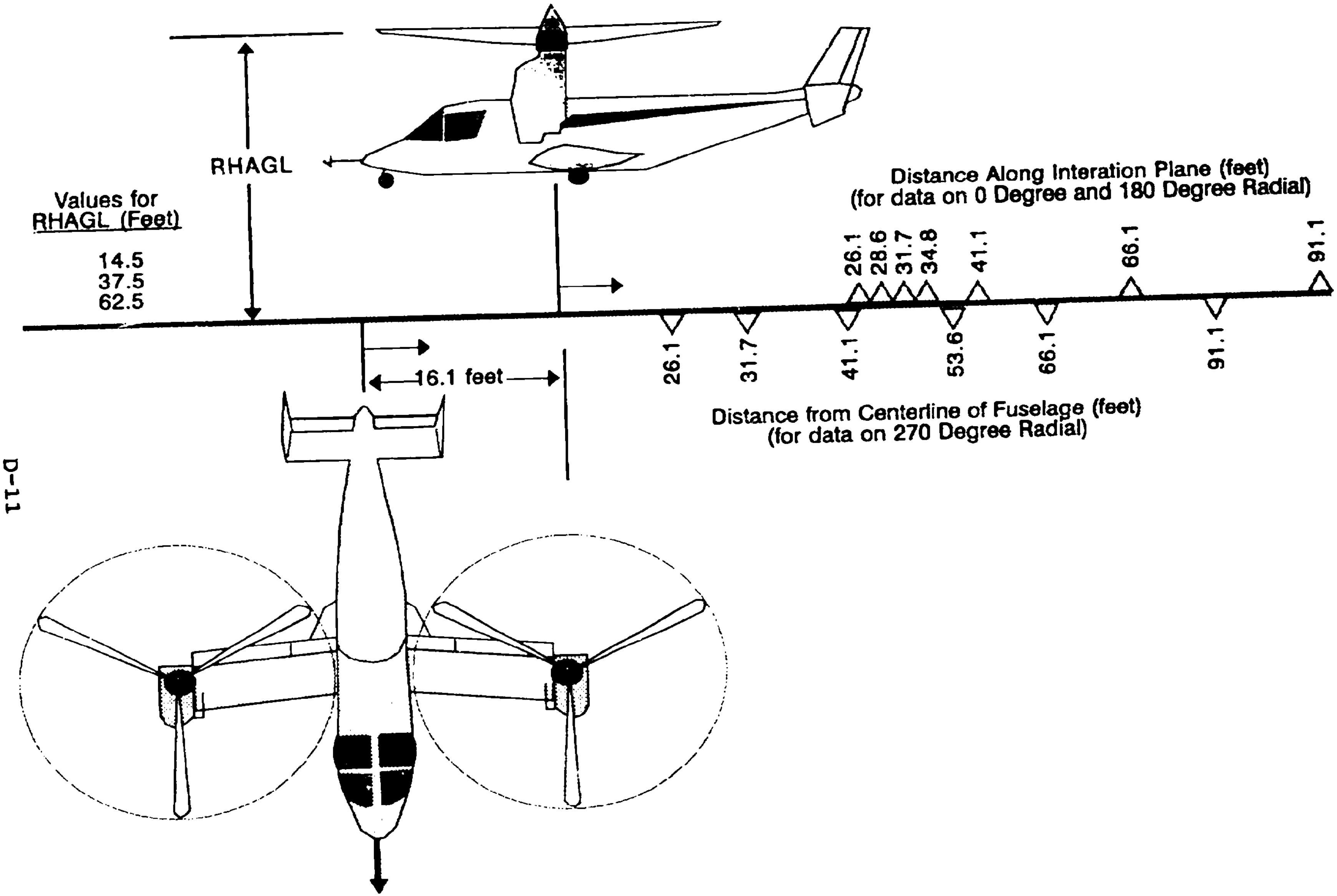


FIGURE D-10 XV-15 FLIGHT TEST DATA MEASUREMENT LOCATIONS

SINGLE ROTOR VELOCITY PROFILE AT RADIUS = 50.0 FT

PROFILE BOUNDARY HEIGHT = 11.49 FT
HALF-VEL.HEIGHT = 4.10 FT
MAX-VEL HEIGHT = 1.15 FT

HEIGHT (FT)	MEAN VELOCITY (FPS)	MEAN VELOCITY (KN)	PEAK VELOCITY (FPS)	PEAK VELOCITY (KN)	MEAN Q (PSF)	PEAK Q (PSF)
.00	.000	.000	.000	.000	.000	.000
1.00	42.306	25.077	78.945	46.796	2.127	7.407
2.00	40.282	23.878	81.231	48.151	1.928	7.842
3.00	32.043	18.994	74.263	44.021	1.220	6.554
4.00	24.823	14.714	65.002	38.531	.732	5.021
5.00	18.565	11.005	59.944	35.533	.410	4.270
6.00	13.240	7.848	51.299	30.408	.208	3.128
7.00	8.829	5.233	39.909	23.657	.093	1.893
8.00	5.319	3.153	27.477	16.288	.034	.897
9.00	2.700	1.600	15.691	9.301	.009	.293
10.00	.964	.571	6.222	3.688	.001	.046

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-11 WALL JET VELOCITY PROFILE OUTPUT FORMAT

prompt (at the bottom of the screen) results in the next 10 lines of data being written to the screen. If the code value <P> is typed, the program returns to the wall jet analysis menu. The typing of code <N> results in the program returning to the master input data menu. If the code <X> is typed, the program returns to the DOS system prompt.

Flight test data, correlated with output from the wall jet option, are presented in section 3 of Volume I of this report for the Bell XV-15, Bell-Boeing MV-22, Sikorsky CH-53E, Sikorsky SH-60B, and Canadair CL-84. Based on the correlation conducted for references D-1 and D-2, it is generally recommended that the wall jet option be used for calculation of velocity profiles at distances greater than 1.5 times the rotor radius from the center of the rotor. At distances less than this value, the mathematical model is not detailed enough to predict rotorwash flowfield characteristics accurately. This limitation is not serious because distances closer to the rotor tip than 1.5 times the rotor radius have little practical reason for being analyzed for rotorwash effects on the environment. Collision avoidance with respect to objects in close proximity to the rotorcraft is the critical issue at this close a distance.

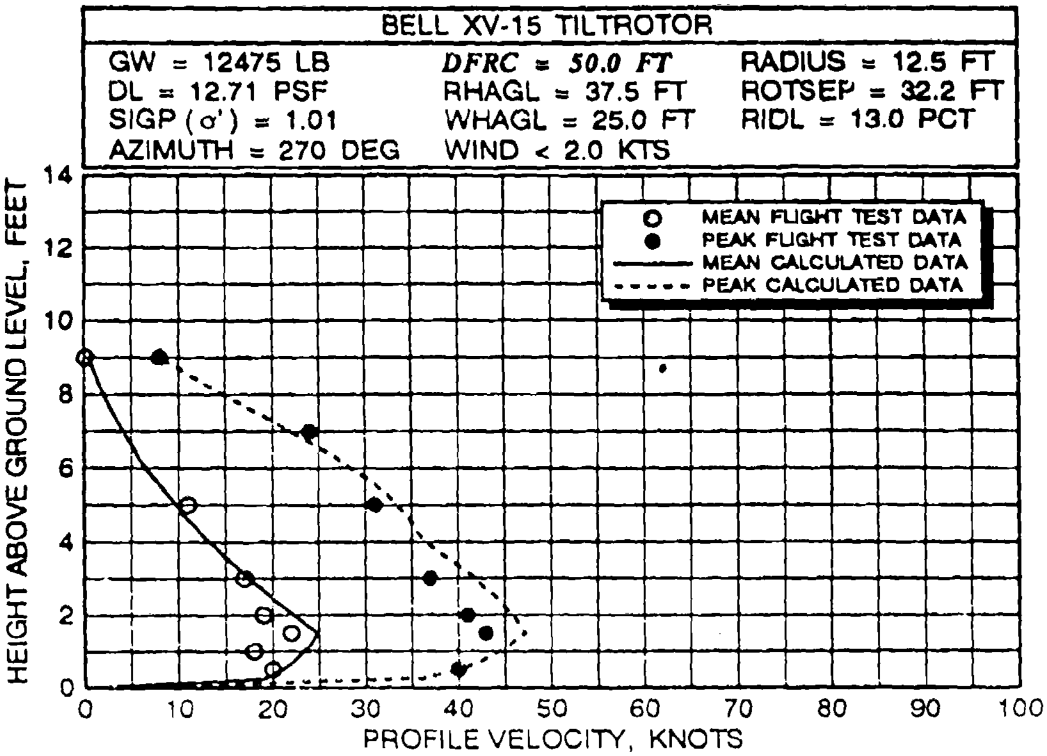


FIGURE D-12 XV-15 VELOCITY PROFILE CORRELATION

D.1.5 THE TWIN-ROTOR INTERACTION PLANE OPTION

The twin-rotor interaction plane option calculates the velocity profile contained in the plane which is oriented perpendicular to the ground and to the line segment which connects the center of both rotor hubs (refer to figure D-1). After choosing the interaction plane option on the velocity analysis option menu, the user must specify the same parameters on the velocity profile status menu that are required with the wall jet option. The only difference between the parameters is the reference position for specification of the horizontal location of the velocity profile with respect to the rotor (the first menu option). For the interaction plane analysis, this distance is referenced as 0 at the intersection of the interaction plane and the line connecting the rotors and not directly to the center of one of the two rotors (i.e., the input value for distance along the interaction plane (DAIP) for a tiltrotor is along a line that is an extension of the fuselage centerline as seen in figure D-10). No velocity profile differences are assumed to exist by the mathematical model for points equidistant along the interaction plane but on opposite sides of the line connecting the rotors. For a tiltrotor, this means that the calculated velocity profiles both

directly in front of and directly aft of the aircraft are the same when equidistant along the interaction plane.

Example output from the interaction plane option is presented in figure D-13. This data format closely resembles that of the wall jet option except that both horizontal and vertical velocity profile components are calculated. The horizontal velocity component is identified by the "H" in the column following the height column and the vertical component by the "V". The mechanics for viewing data on the screen (if more data exist than will fit on one screen frame) and for transferring to other menus are exactly as are described for the wall jet option.

TWIN ROTOR INTERACTION PLANE VELOCITY PROFILE AT STATION = 50.0 FT

HEIGHT (FT)		MEAN VELOCITY (FPS)	MEAN VELOCITY (KN)	PEAK VELOCITY (FPS)	PEAK VELOCITY (KN)	MEAN Q (PSF)	PEAK Q (PSF)
.00	H	.000	.000	.000	.000	.000	.000
	V	.000	.000	.000	.000	.000	.000
1.00	H	63.626	37.715	103.992	61.643	4.811	12.852
	V	21.760	12.899	35.555	21.082	.563	1.503
[illegible]0	H	66.665	39.517	108.960	64.508	5.282	14.110
	V	24.133	14.305	39.443	23.381	.692	1.849
3.00	H	65.800	39.004	107.545	63.749	5.146	13.746
	V	25.136	14.900	41.082	24.352	.751	2.006
4.00	H	64.912	38.478	106.093	62.889	5.008	13.377
	V	26.094	15.468	42.649	25.281	.809	2.162

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-13 INTERACTION PLANE VELOCITY PROFILE OUTPUT FORMAT

Output from the interaction plane option, correlated with XV-15 flight test data, is presented in figure D-14 as an example. These data are excerpted from reference D-2. Other original flight test data for both the Bell XV-15, Bell-Boeing MV-22, and Canadair CL-84 (tiltwing) are documented in section 3 of Volume I of this report.

Several practical recommendations need to be noted for users of the interaction plane option. When analyzing tiltrotor and tiltwing configurations, the user must be careful to avoid choosing analysis locations that are coincident with components of the nose or tail structure on the aircraft. Also, locations in close proximity to the nose or tail of a real aircraft should not be expected to have rotorwash flowfield characteristics identical to calculated velocity profiles. At these locations unmodeled airframe aerodynamic interferences significantly influence the rotorwash flowfield structure. Flight test data

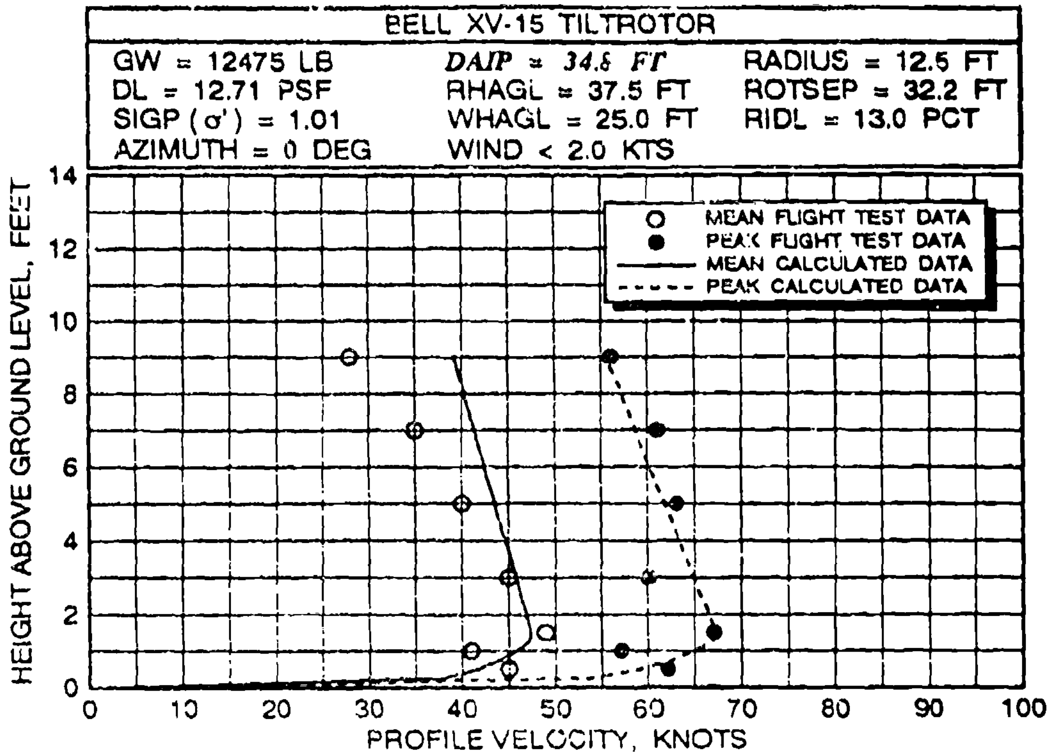


FIGURE D-14 XV-15 INTERACTION PLANE VELOCITY PROFILE CORRELATION

obtained from the XV-15, MV-22, and CL-84 indicate that measured mean and peak velocity profiles at points equidistant along the interaction plane (both in front of and aft of an actual aircraft) often do not yield identical results as might be expected. Therefore, output from this analysis option should be calibrated with flight test data whenever possible in an attempt to determine whether positions forward or aft of the aircraft may be more critical for analysis.

D.1.6 GROUND VORTEX ANALYSIS OPTION

A ground vortex structure is formed when ambient wind and/or rotorcraft translational velocity overcome the rotor-induced wall jet flowfield. A diagram of the ground vortex is presented in figure D-15. Due to the elementary nature of the mathematical model formulation used in the ROTWASH program, the ground vortex option should be used with caution. As discussed in section 2 of Volume I of this report, almost no test data exist to validate the mathematical model. Also, the single main rotor helicopter is the only configuration that can be analyzed with the model as presently formulated. Since all examples presented up to this point in the user's guide have been for the XV-15, it is necessary to define input data for a single main rotor helicopter

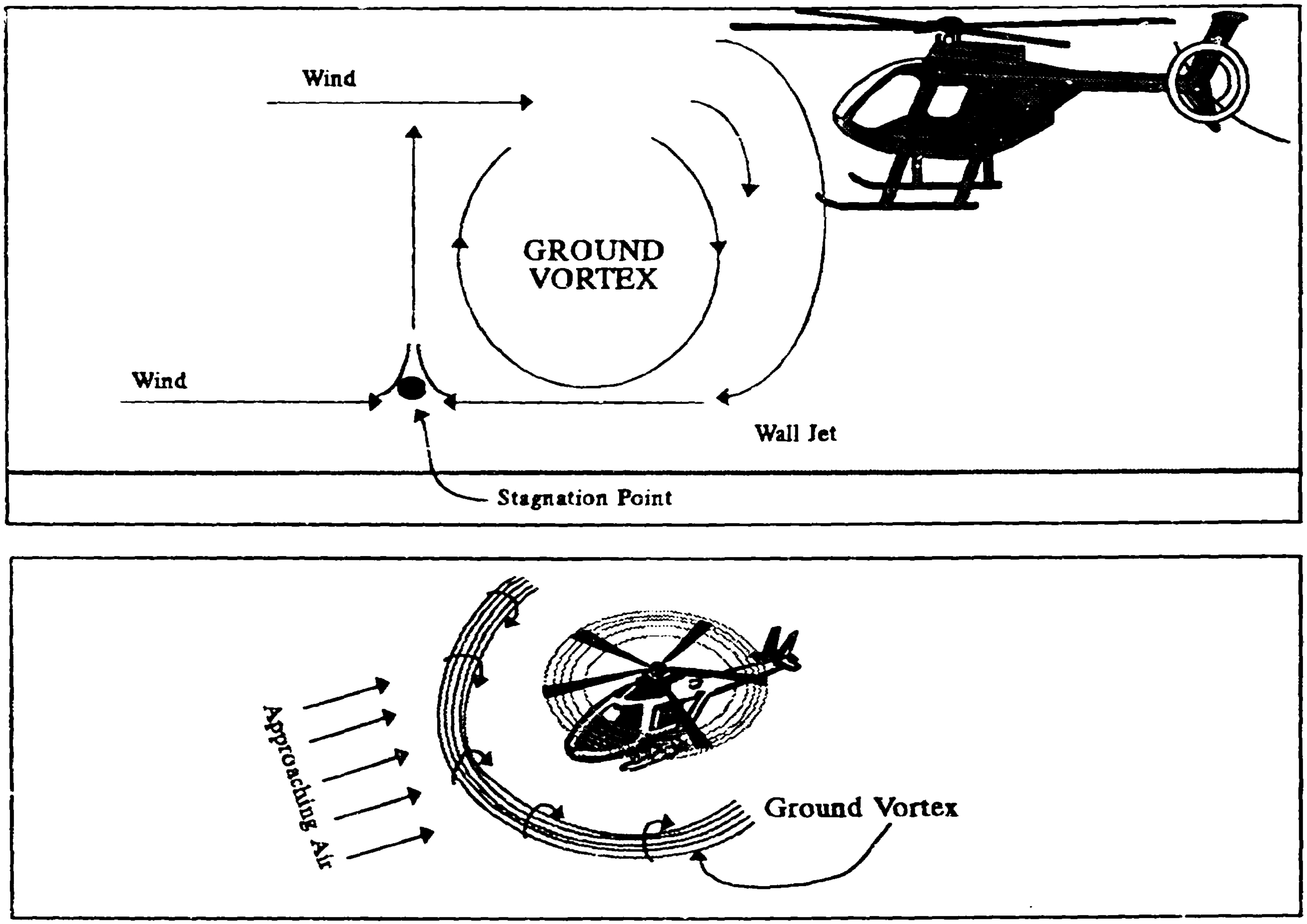


FIGURE D-15 GROUND VORTEX STRUCTURAL CHARACTERISTICS

ROTWASH USER INPUT DATA MENU			
CODE	PARAMETER	VALUE	UNITS
A	NUMBER OF ROTORS (1 OR 2)	1	-ND-
B	HUB TO HUB ROTOR SEPARATION	.0	FT
C	ROTOR RADIUS	39.5	FT
D	GROSS WEIGHT	56000.0	LB
E	FUSELAGE DOWNLOAD FACTOR	5.0	PCT
F	ROTOR HEIGHT ABOVE GROUND	30.0	FT
G	SHAFT TILT ANGLE (<20 DEG)	.0	DEG
H	AIR DENSITY RATIO	1.0000	ND
I	AMBIENT WIND (-10 TO 10 KT)	.0	KT
ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==>			

FIGURE D-16 CH-53E INPUT DATA FOR THE GROUND VORTEX EXAMPLE

before the ground vortex option is explained in detail. The Sikorsky CH-53E configuration has been chosen for this task. The main input data menu for this configuration, as typed into the program, is presented in figure D-16.

The ground vortex analysis option is specified by selection of the character <G> on the velocity analysis option menu as shown in figure D-5. The user is then required to complete the ground/disk vortex input data menu which is presented in figure D-17. Two of the parameters specified on this menu are rotorcraft configuration parameters. These parameters are the rotor tip speed (feet/second) and the number of rotor blades. The next parameter to be specified is the rotorcraft translational velocity with respect to the surrounding air mass (i.e., an input of 15 knots can be either 15 knots ground speed on a no-wind day or 0 knots ground speed on a day with a 15-knot headwind). Each of these values is input with the keyboard using the same techniques that have been previously discussed.

The next four menu parameters define the position in three-dimensional space (feet) where the velocity profile will be calculated (see figure D-18). The positive directions for the coordinate system are aft and right from the center of the rotor. Therefore, in order to calculate a slice of the ground vortex directly in front of the rotor, a negative X-value (longitudinal position) is input along with a zero Y-value (lateral position). The Z-axis increment (feet) and maximum calculation height (feet) parameters define the number of points that are calculated between ground level and the maximum height of interest.

GROUND/DISK VORTEX INPUT DATA MENU (FOR SINGLE MAIN ROTOR HELICOPTERS ONLY)			
CODE	PARAMETER	VALUE	UNITS
A	ROTOR TIP SPEED	733.00	FPS
B	NUMBER OF ROTOR BLADES	7.00	-ND-
C	TRANSLATIONAL SPEED	16.00	KTS
D	XT POSITION	-60.00	FT
E	YT POSITION	.00	FT
F	ZT CALCULATION INCREMENT	2.00	FT
G	MAXIMUM CALCULATION HEIGHT	20.00	FT

ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==>

FIGURE D-17 GROUND/DISK VORTEX INPUT DATA MENU

After each input data parameter has been specified, the user types the **<RETURN>** key to initiate the analysis. The response of the program is to list three calculated parameters which are followed by a prompt. An example of this response is provided in figure D-19. The calculated values are the nondimensionalized rotor height above ground and two advance ratio parameters. The program prompt following the screen output requires the user to input the ground vortex strength ratio which is obtained from the graph in figure D-20 using the three calculated parameters. Background on the use of this figure is discussed in section 2 of Volume I of this report. The limits presented on the graph in figure D-20 define the advance ratio range wherein the ground vortex would be expected to occur. At advance ratios much less than 0.035, the ground vortex does not have favorable conditions for formation. At advance ratios slightly greater than 0.055, the ground vortex is dispersed by the rotor because the translational velocity relative to the air mass is too high for the vortex to maintain position. After the user has entered the ground vortex strength ratio, the program calculates the ground vortex circulation and the position of the ground vortex core with respect to the axis system presented in figure D-18. This output is also presented in figure D-19 below the prompt for the ground vortex strength ratio.

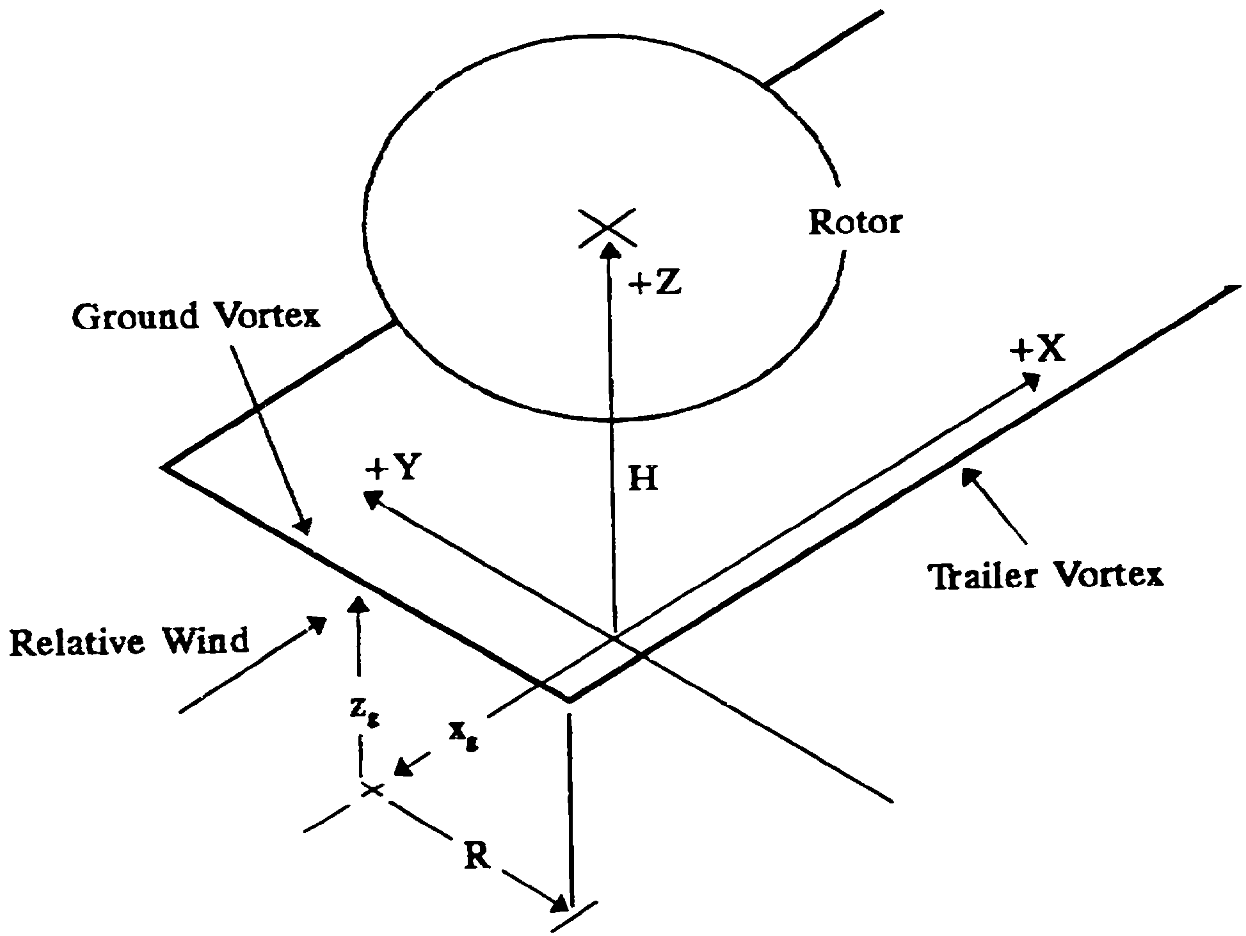


FIGURE D-18 HORSESHOE VORTEX GEOMETRY FOR CALCULATION OF GROUND VORTEX HAZARD POTENTIAL

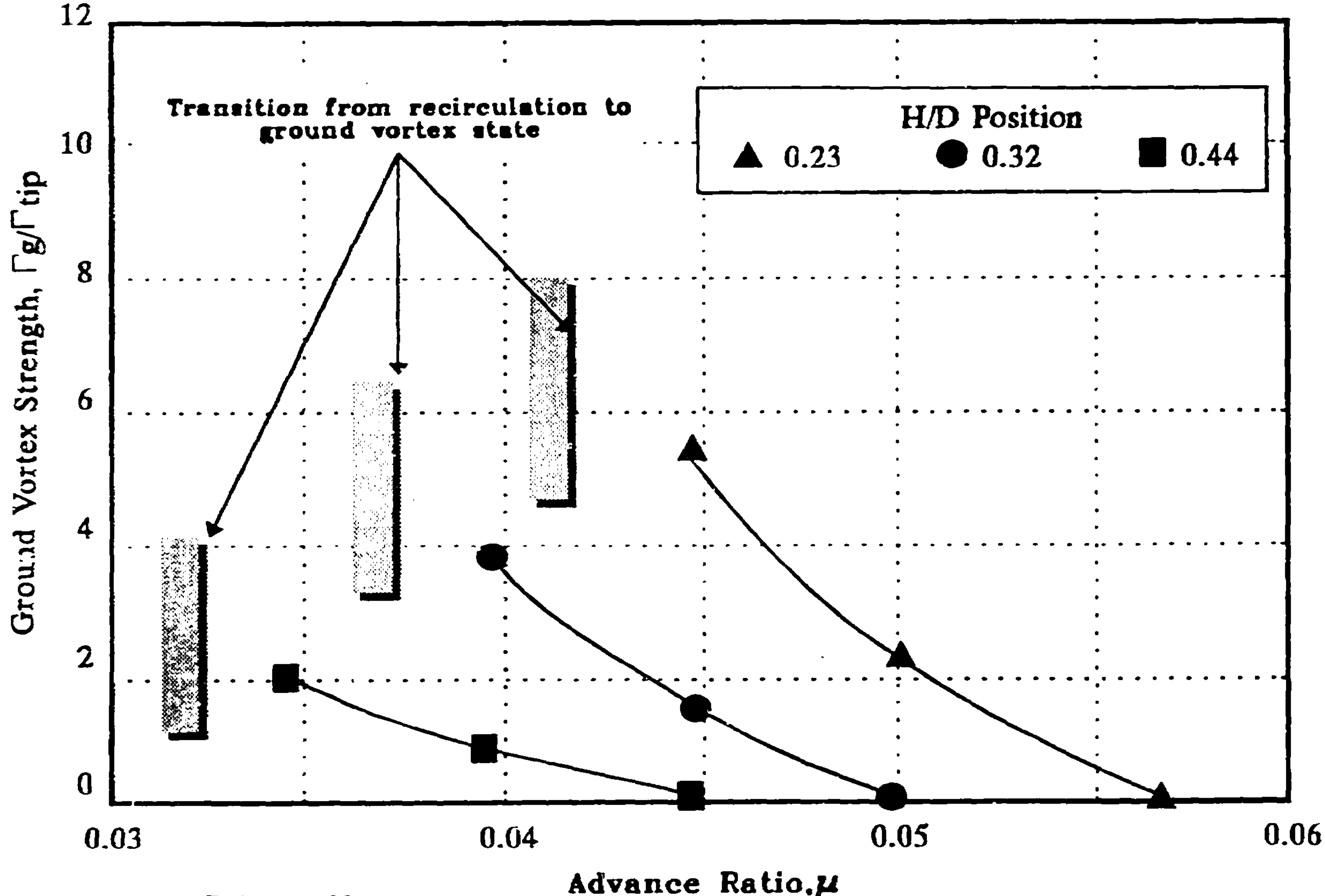
```
ROTOR HEIGHT ABOVE GROUND H/D        .3797
ADVANCE RATIO MU-STAR                .5373
ADVANCE RATIO MU                     .0368


ENTER GROUND VORTEX STRENGTH RATIO
      (SEE FIGURE D-20)            ==> 3.


      GROUND VORTEX CORE POSITION

X-LOCATION (XXGV)         =    -59.14  FT
Y-LOCATION (ZZGV)         =      9.15  FT

GROUND VORTEX CIRCULATION =    732.35  FT**2/SEC


      PRESS <RETURN> TO CONTINUE
```

FIGURE D-19 GROUND VORTEX ANALYSIS INTERMEDIATE OUTPUT

Engineering data from the ground vortex analysis option is obtained by typing the **<RETURN>** key after the vortex position parameters are displayed. An example of the output format is presented in figure D-21. Calculated field velocities at the various points along the profile Z-axis are presented in both a vectorial XYZ component format and as a total resolved magnitude in units of feet per second and knots. These same data are also provided to the user as dynamic pressures in units of pounds per square feet.

D.1.7 DISK EDGE VORTEX ANALYSIS OPTION

The disk edge vortex analysis option was developed to provide a capability to estimate the strength of trailing vortices behind helicopters in forward flight as described by figure D-22. Like the ground vortex option, this option is limited to use with the single main rotor helicopter configuration. Approximations of vortex core size are not calculated by the mathematical model and must be estimated using flight test data. Available flight test data are presented in section 3.6 of Volume I of this report. All examples presented in the user's guide for this analysis option utilize the same CH-53E input data array that was described previously.



Source: Reference 35.

FIGURE D-20 CALCULATED GROUND VORTEX CIRCULATION STRENGTH

HEIGHT		MEAN VELOCITY		MEAN Q
(FT)		(FPS)	(KN)	(PSF)
.00	X	-24.582	-14.572	.718
	Y	.000	.000	.000
	Z	.000	.000	.000
	T	24.582	14.572	.718
2.00	X	-25.790	-15.288	.790
	Y	.000	.000	.000
	Z	1.013	.601	.001
	T	25.810	15.299	.792
4.00	X	-30.173	-17.886	1.082
	Y	.000	.000	.000
	Z	2.868	1.700	.010
	T	30.309	17.966	1.092

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-21 GROUND VORTEX VELOCITY FIELD OUTPUT DATA

Execution of the disk edge vortex option is initiated by choosing **<D>** on the velocity analysis option menu shown in figure D-5. The ground/disk vortex input data menu, shown in figure D-17, must then be completed as described in the previous section. All sign conventions used in the specification of locations for the calculation of field velocities are the same as for the ground vortex option. After the input data menu is completed, the analysis option is executed by typing the **<RETURN>** key.

The initial program response, figure D-23, is to write to the screen the calculated values for the vortex circulation and the settling angle of the trailing vortex components as defined in figure D-22 for a forward-flight velocity of 50 knots and a rotor height above ground of 100 feet. When executing this option, it is important that the user confirm that the calculated settling angle is less than approximately 20 degrees. At settling angles larger than this value, the airspeed of the helicopter is probably too slow to sustain the formation of the trailing edge vortex system which is predicted using this mathematical model, and results should be considered suspect. User specified velocity field calculations are presented after the **<RETURN>** key is typed in the same format as was discussed with the ground vortex option. An example output for the CH-53E is presented in figure D-24.

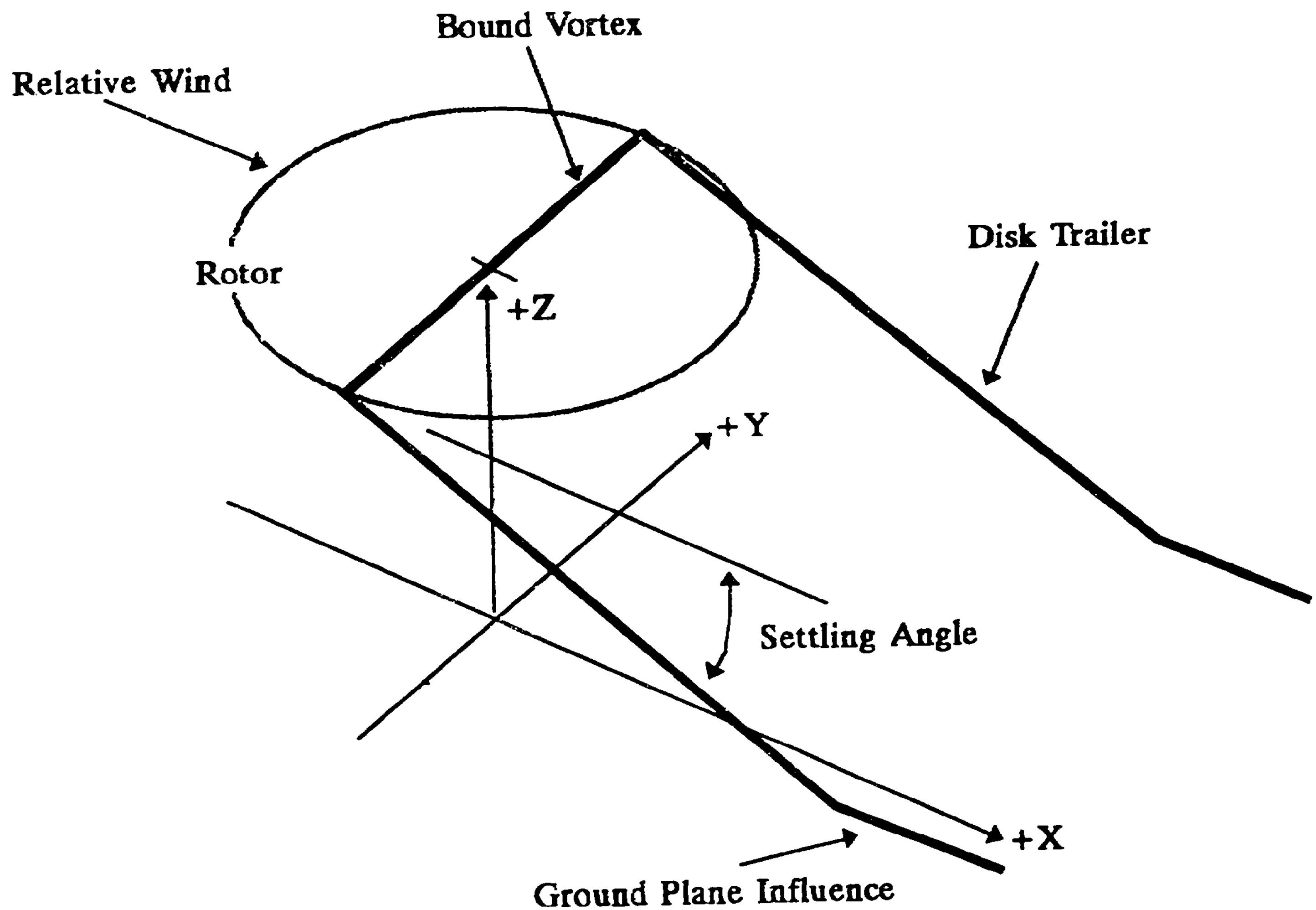


FIGURE D-22 HORSESHOE VORTEX GEOMETRY FOR CALCULATION OF FORWARD FLIGHT WAKE HAZARD POTENTIAL

Other features of the mathematical model which should be noted are described below.

1. The calculated trailing vortex strength does not decay as a function of increasing distance from the helicopter or with increasing time. This weakness in the model will affect correlation with flight test data and could result in predicted values that are greater than measured values for field velocities.

2. The decay of the trailing vortex structure after impingement with the ground is not modeled. Any prediction of field velocities behind the initial impingement point should not be considered valid. The location of the impingement point with respect to the ground and the location of points specified for velocity field calculations must be checked by hand calculation to ensure that geometry constraints are not violated. This is accomplished by using the rotor height and the settling angle to calculate the horizontal distance behind the helicopter where the impingement occurs.

D.1.8 PERSONNEL OVERTURNING FORCE AND MOMENT ANALYSIS

The personnel overturning force and moment analysis model is formulated for use with both the single main rotor and twin-rotor configurations. The initial task of the model is to calculate the velocity profile for a specified location. The calculated velocity profile is then integrated over the projected area of a human body to obtain estimates of the applied aerodynamic force and moment. This analysis technique is summarized in figure D-25.

Use of the overturning force and moment option is initiated by choosing <H> (for hazard) on the program logic/comment menu. This is followed by the choice of <M> (for overturning force/moment) on the hazard analysis option menu as shown in figure D-6. The user then specifies the parameters listed on the overturning force and moment data menu presented in figure D-26. The first parameter on this menu specifies the use of either the wall jet or the interaction plane analysis for creation of velocity profile data. The second option specifies the use of either the "large" (6 feet in height) or "small" (4 feet in height) human body mathematical model. The third parameter provides the user the capability to specify a graphics output filename (assuming this option has been toggled ON using the program logic/comment menu). If the user executes the option without changing the filename and a file already exists with the same filename, the user is notified and required to change the filename. Three of the last four menu variables define the locations that are to be analyzed using the option. These variables, all in units of feet, are the initial station position for analysis, the increment in station position, and the final

DISK VORTEX VELOCITY PROFILE DATA

X-LOCATION (XT)	=	150.00	FT
Y-LOCATION (YT)	=	.00	FT
VORTEX CIRCULATION	=	5441.24	FT**2/SEC
VORTEX CIRCULATION	=	505.51	M**2/SEC
5-M INITIAL CIRCULATION	=	232.37	M**2/SEC
SETTLING ANGLE	=	9.29	DEG

PRESS <RETURN> TO CONTINUE

FIGURE D-23 DISK EDGE VORTEX OPTION INTERMEDIATE OUTPUT

HEIGHT (FT)		MEAN VELOCITY (FPS)	MEAN VELOCITY (KN)	MEAN Q (PSF)
.00	X	-4.052	-2.402	.020
	Y	.000	.000	.000
	Z	.000	.000	.000
	T	4.052	2.402	.020
50.00	X	-6.444	-3.820	.049
	Y	.000	.000	.000
	Z	-27.295	-16.180	.885
	T	28.046	16.625	.935
100.00	X	-5.735	-3.399	.039
	Y	.000	.000	.000
	Z	-30.049	-17.812	1.073
	T	30.592	18.134	1.112

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-24 VELOCITY FIELD OUTPUT DATA FROM THE DISK EDGE VORTEX OPTION

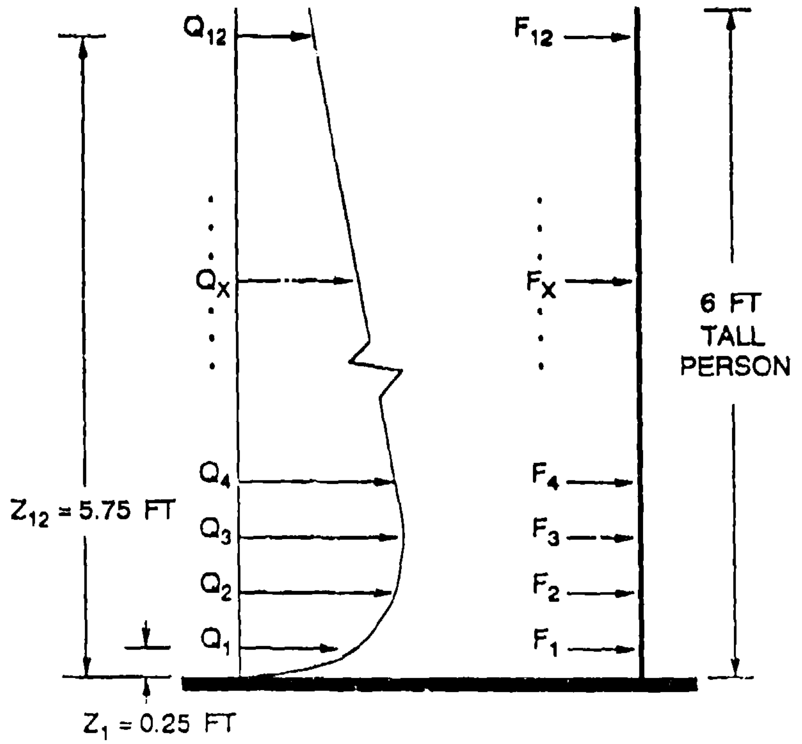


FIGURE D-25 OVERTURNING FORCE AND MOMENT CALCULATION PROCEDURES

station position, respectively. The fourth parameter is the user option to specify a minimum boundary layer height (discussed in section D.1.4 of the user's guide). The mechanics for input of the desired values using this menu are as described for previous menus.

After the analysis is executed by typing the **<RETURN>** key, the calculated results are written out in the format presented in figure D-27. Three columns of data are written using this format. The first column identifies either the distance from rotor center (DFRC) for the wall jet option or the distance along the interaction plane (DAIP) for the interaction plane option.

The second and third columns are the associated total force and total moment values calculated for the projected area of a human body. Example data for the XV-15 using this option are presented in figure D-28 for reference. At the bottom of the screen, the user is required to return to the previous menu by typing **<P>**,

OVERTURNING FORCE/MOMENT DATA MENU

CODE	PARAMETER	VALUE	UNITS
A	<W>ALL JET OR <I>NTERACTION PLANE	W	
B	<L>ARGE OR <S>MALL PERSON	L	
C	DATA OUTPUT FILENAME	OTDFRC.PTS	
D	INITIAL STATION POSITION	50.00	FT
E	HORIZONTAL INCREMENT	10.00	FT
F	MAXIMUM STATION POSITION	100.00	FT
G	MINIMUM BOUNDARY LAYER HEIGHT	1.50	FT

ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==>

FIGURE D-26 OVERTURNING FORCE AND MOMENT DATA MENU

SUMMARY OF OVERTURNING FORCES AND MOMENTS

RADIUS (FT)	TOTF (LB)	TOTM (FT-LB)
50.00	42.721	114.596
60.00	33.708	91.718
70.00	25.046	69.346
80.00	17.520	49.892
90.00	11.511	33.382
100.00	6.926	20.269

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-27 SIMPLIFIED OUTPUT FORMAT FOR THE OVERTURNING FORCE AND MOMENT ANALYSIS

the master input data menu by typing <N>, or to exit the program by typing <X>. By typing <C>, the user can view the next video screen of data if more than one screen of data is generated. Otherwise, the <C> option works identically to the <P> option.

The user can examine the detailed calculations used to create the summary output by specifying the desired analysis location as the initial station position. This input must then be followed by specification of the increment value as 0.0 or only the summary output will appear (as shown in figure D-29). The resulting "large" person output using this option is presented on two screen frames as shown in figure D-30. The first output frame presents a summary of the velocity profile calculations as a function of height above ground at the specified station position. The second output frame presents the associated calculations for dynamic pressure, overturning force, and overturning moment. The last two columns in the second table are values of total force and moment summed for the incremental increase in height.

In this example, the force and moment values of 42.7 pounds and 114.6 foot-pounds, respectively, at 5.75 feet are the total force and moment values that would normally be printed out in the summary output (figure D-27). These values are checked by totaling the individual height-related values in the overturning force and moment columns (second and third columns). An example output for the second screen of the "small" person option is presented in figure D-31 for reference.

Both qualitative and quantitative overturning force and moment data are presented in section 5 of volume I of this report correlated with ROTWASH program output for the Bell XV-15, Sikorsky CH-53E, and the Sikorsky S-61. These calculated data all assume a coefficient of drag for a human body of 1.1 (which according to Hoerner, reference D-6, can vary from 1.0 to approximately 1.3).

D.1.9 PARTICULATE CLOUD ANALYSIS OPTION

The methodology used in the calculation of particulate cloud size is presented in section 5.8 of volume I of this report along with a very limited amount of flight test data. This option is applicable to both single main rotor and twin-rotor configurations. The particulate cloud geometry utilized in the analysis option is presented in figure D-32.

The particulate cloud option is initiated with the typing of <C> on the hazard analysis option menu as shown in figure D-6. The screen that is written subsequently presents the user with a prompt for input of the terrain erosion factor. The value for this factor is chosen from the graph in figure D-33.

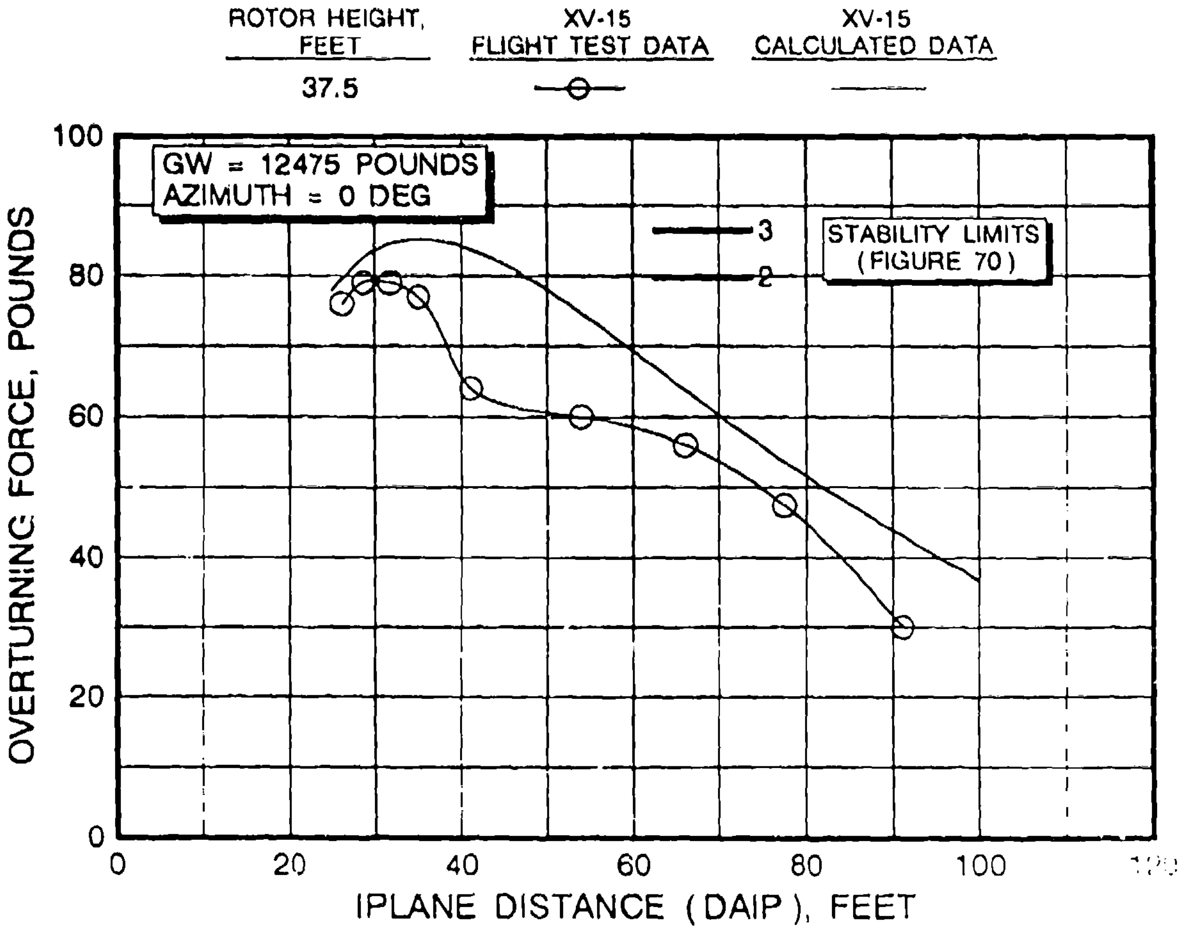


FIGURE D-28 BELL XV-15 OVERTURNING FORCE AS A FUNCTION OF DISTANCE ALONG THE INTERACTION PLANE (0 DEGREE AZIMUTH)

OVERTURNING FORCE/MOMENT DATA MENU

CODE	PARAMETER	VALUE	UNITS
A	<W>ALL JET OR <I>NTERACTION PLANE	W	
B	<L>ARGE OR <S>MALL PERSON	L	
C	DATA OUTPUT FILENAME	OTDFRC.PTS	
D	INITIAL STATION POSITION	50.00	FT
E	HORIZONTAL INCREMENT	.00	FT
F	MAXIMUM STATION POSITION	100.00	FT
G	MINIMUM BOUNDARY LAYER HEIGHT	1.50	FT

ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==>

FIGURE D-29 MENU SPECIFICATION OF DETAILED FORCE/MOMENT OUTPUT

SINGLE ROTOR VELOCITY PROFILE AT RADIUS = 50.0 FT

HEIGHT (FT)	MEAN VELOCITY (FPS)	(KN)	PEAK VELOCITY (FPS)	(KN)	MEAN Q (PSF)	PEAK Q (PSF)
.25	34.705	20.572	64.762	38.389	1.431	4.984
.75	40.602	24.068	75.767	44.912	1.959	6.822
1.25	43.676	25.890	81.502	48.312	2.267	7.894
1.75	42.515	25.202	82.535	48.924	2.148	8.096
2.25	38.121	22.597	79.742	47.269	1.727	7.557
2.75	34.004	20.157	76.248	45.197	1.374	6.909
3.25	30.146	17.870	72.134	42.759	1.080	6.184
3.75	26.537	15.730	67.491	40.007	.837	5.413
4.25	23.170	13.734	63.591	37.695	.638	4.806
4.75	20.041	11.880	61.475	36.441	.477	4.491
5.25	17.147	10.164	58.134	34.460	.349	4.016
5.75	14.485	8.586	53.785	31.882	.249	3.438

TYPE <RETURN> TO CONTINUE

SINGLE ROTOR FORCE PROFILE AT RADIUS = 50.0 FT

HEIGHT (FT)	PEAK Q (PSF)	FOVER (LB)	OVERM (FT-LB)	TOT F (LB)	TOT M (FT-LB)
.25	4.984	3.016	.754	3.016	.754
.75	6.822	4.128	3.096	7.143	3.850
1.25	7.894	4.776	5.970	11.919	9.820
1.75	8.096	4.898	8.571	16.817	18.391
2.25	7.557	4.572	10.287	21.389	28.678
2.75	6.909	4.180	11.495	25.569	40.174
3.25	6.184	3.741	12.159	29.311	52.333
3.75	5.413	3.275	12.282	32.586	64.615
4.25	4.806	2.908	12.357	35.493	76.972
4.75	4.491	2.717	12.907	38.211	89.879
5.25	4.016	2.430	12.757	40.641	102.636
5.75	3.438	2.080	11.960	42.721	114.596

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-30 DETAILED OUTPUT FORMAT FOR THE "LARGE" PERSON ANALYSIS OPTION

SINGLE ROTOR FORCE PROFILE AT RADIUS = 50.0 FT

HEIGHT (FT)	PEAK Q (PSF)	FOVER (LB)	OVERM (FT-LB)	TOT F (LB)	TOT M (FT-LB)
.25	4.984	1.919	.480	1.919	.480
.75	6.822	2.627	1.970	4.546	2.450
1.25	7.894	3.039	3.799	7.585	6.249
1.75	8.096	3.117	5.455	10.702	11.703
2.25	7.557	2.909	6.546	13.611	18.250
2.75	6.909	2.660	7.315	16.271	25.565
3.25	6.184	2.381	7.738	18.652	33.303
3.75	5.413	2.084	7.816	20.736	41.118

TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>

FIGURE D-31 DETAILED OUTPUT FORMAT FOR THE SECOND SCREEN FRAME OF THE "SMALL" PERSON ANALYSIS OPTION

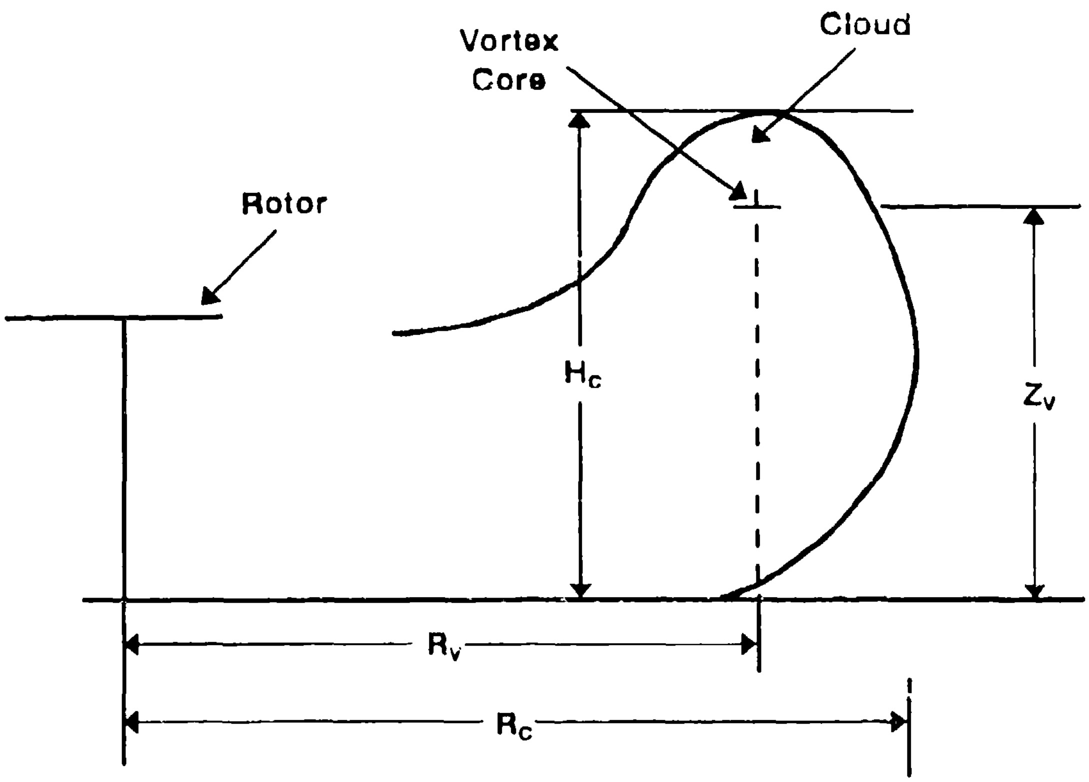


FIGURE D-32 PARTICULATE CLOUD ANALYSIS GEOMETRY DEFINITION

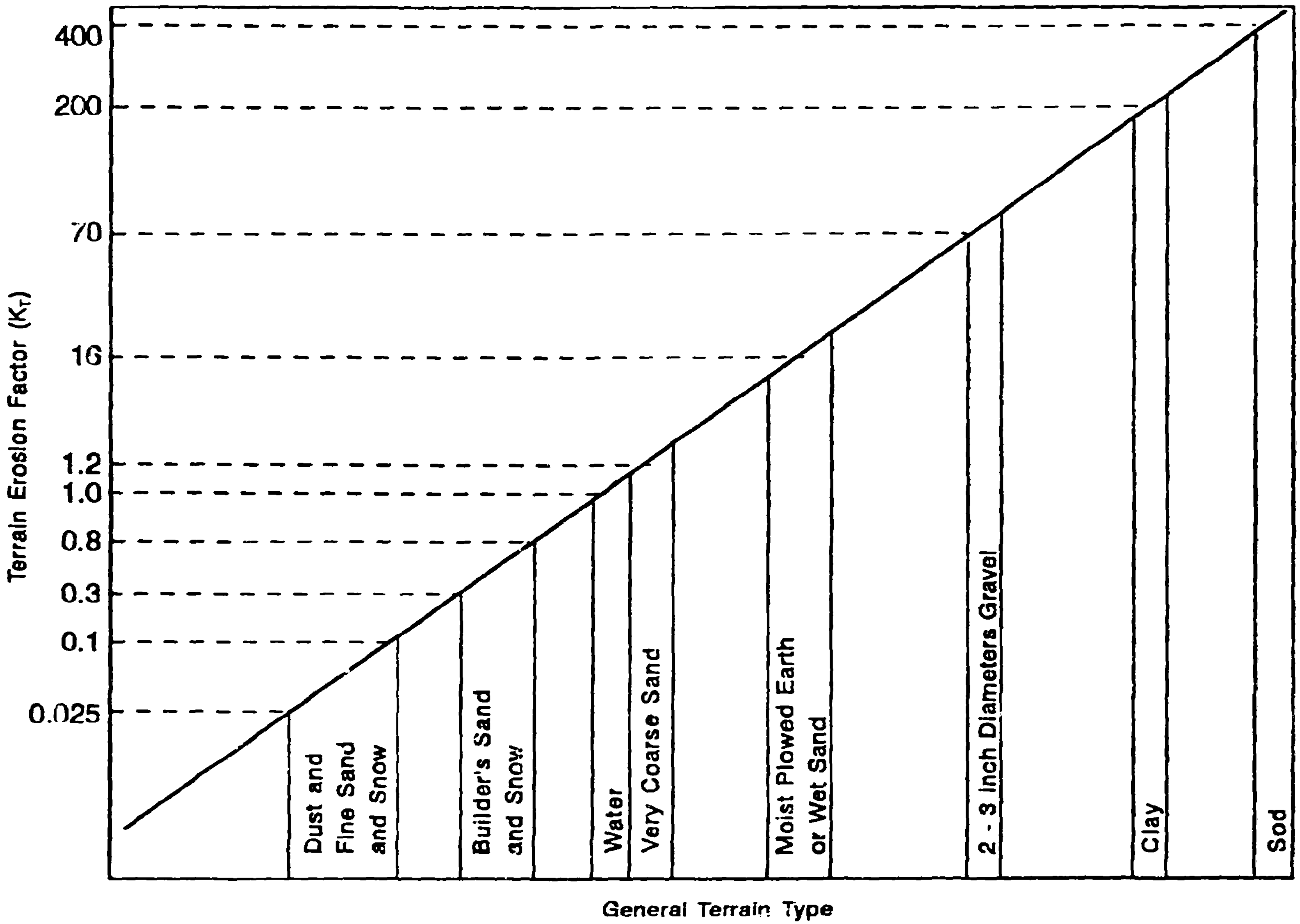


FIGURE D-33 APPROXIMATE VALUES FOR THE TERRAIN EROSION FACTOR (K_T) AS IDENTIFIED IN THE LITERATURE

The output format for the particulate cloud option is designed for both single main rotor and twin-rotor aircraft as shown in figure D-34. In this example, using the XV-15, the particulate cloud boundaries located at the 90- and 270-degree azimuths (out the span of the wing) are specified by the single rotor or "SR" row of output values. The interaction plane or "IP" row defines the cloud boundaries which exist straight out in front of and directly aft of the aircraft along the aircraft centerline. If a single main rotor configuration is being evaluated, the "IP" row in the printout will contain all zeros.

```
              ENTER TERRAIN EROSION FACTOR (-ND-) ==> 0.4

                         SUMMARY OF CLOUD BOUNDARIES

                     RC AND RV ARE FROM ROTOR CENTER (FT)

                     RC          RV          ZV          HC

          SR        80.1        62.8        26.3        37.6
          IP       113.0        88.7        37.2        53.0

          QSMAX =    13.5 PSF



      TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE, E<X>IT ==>
```

FIGURE D-34 PARTICULATE CLOUD ANALYSIS OPTION OUTPUT

D.2 ROTWASH PROGRAM DATA OUTPUT FILE FORMATS

Four data output file formats can be specified from the ROTWASH program for use with computer graphics programs. Two of these output file formats are generated by the wall jet and interaction plane velocity profile analysis options. The other two formats are generated by the personnel overturning force and moment option. These file formats save the summary force and moment data for both the wall jet and interaction plane cases.

The first two lines in each of the four file formats are user-specified comments. These two comment lines are typed in through use of the program logic/comment menu. The rest of the data in each of the file formats is either header information or engineering data. The example files presented in this section are written for direct input to the TECPLOT Graphics Program which is written by AMTEC Engineering. This graphics program is one of several IBM PC/PC-compatible engineering graphics programs

presently on the market. Users that do not have access to this program can easily modify the ROTWASH FORTRAN code for other types of graphics programs by modifying the appropriate write statements. Table 1 provides the user with a cross reference of the figure number for each of the four output types and the source location for the associated FORTRAN code that can be modified (see program listings in appendix E).

TABLE D-1 GRAPHICS FILE/SOURCE CODE REFERENCE MATRIX

FILE OUTPUT TYPE	FIGURE	SOURCE CODE LOCATION
Wall Jet Velocity Profile Output	D-35	Subroutine WJVEL
Interaction Plan Velocity Profile Output	D-36	Subroutine IPVEL
Overturning Force/Moment Summary (Wall Jet)	D-37	Subroutine HWJVEL
Overturning Force/Moment Summary (Interaction Plan)	D-38	Subroutine HIPVEL

```
            XV-15 CHARACTERISTICS ARE USED AS INPUT DATA
            GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS

TITLE="VELOCITY PROFILE, DFRC = 50.0 FT, GW = 13000 LB, WAGL = 25.0 FT"
VARIABLES = X,HT
ZONE T = "MEAN PROFILE, KTS", I=11, F=POINT
    .0     .00
  25.1    1.00
  23.9    2.00
  19.0    3.00
  14.7    4.00
  11.0    5.00
   7.8    6.00
   5.2    7.00
   3.2    8.00
   1.6    9.00
    .6   10.00
ZONE T = "PEAK PROFILE, KTS", I=11, F=POINT
    .0     .00
  46.8    1.00
  48.2    2.00
  44.0    3.00
  38.5    4.00
  35.5    5.00
  30.4    6.00
  23.7    7.00
  16.3    8.00
   9.3    9.00
   3.7   10.00
ZONE T = "PEAK Q, PSF", I=11, F=POINT
    .0     .00
   7.4    1.00
   7.8    2.00
   6.6    3.00
   5.0    4.00
   4.3    5.00
   3.1    6.00
   1.9    7.00
    .9    8.00
    .3    9.00
    .0   10.00
```

FIGURE D-35 EXAMPLE WALL JET OPTION GRAPHICS FILE FORMAT

```
XV-15 CHARACTERISTICS ARE USED AS INPUT DATA
GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS
TITLE="VELOCITY PROFILE, DAIP = 50.0 FT, GW = 13000 LB, WAGL = 25.0 FT"
VARIABLES = X,HT
ZONE T = "MEAN PROFILE, KTS", I=11, F=POINT
    .0     .00
  37.7    1.00
  39.5    2.00
  39.0    3.00
  38.5    4.00
  37.9    5.00
  37.4    6.00
  36.8    7.00
  36.3    8.00
  35.7    9.00
  35.1   10.00
ZONE T = "PEAK PROFILE, KTS", I=11, F=POINT
    .0     .00
  61.6    1.00
  64.6    2.00
  63.7    3.00
  62.9    4.00
  62.0    5.00
  61.1    6.00
  60.2    7.00
  59.3    8.00
  58.3    9.00
  57.4   10.00
ZONE T = "PEAK Q, PSF", I=11, F=POINT
    .0     .00
  12.9    1.00
  14.1    2.00
  13.7    3.00
  13.4    4.00
  13.0    5.00
  12.6    6.00
  12.3    7.00
  11.9    8.00
  11.5    9.00
  11.1   10.00
```

FIGURE D-36 EXAMPLE INTERACTION PLANE OPTION GRAPHICS FILE FORMAT

```
XV-15 CHARACTERISTICS ARE USED AS INPUT DATA
GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS
TITLE="SINGLE ROTOR DFRC DATA"
VARIABLES = DFRC,TOTF,TOTM
ZONE T = "GW = 13000 LB, WAGL = 25.0 FT", I=6, F=POINT
  50.00    42.72    114.60
  60.00    33.71     91.72
  70.00    25.05     69.35
  80.00    17.52     49.89
  90.00    11.51     33.38
 100.00     6.93     20.27
```

FIGURE D-37 EXAMPLE PERSONNEL OVERTURNING FORCE AND MOMENT GRAPHICS FILE FORMAT CREATED WITH THE WALL JET ANALYSIS OPTION

```
        XV-15 CHARACTERISTICS ARE USED AS INPUT DATA
        GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS

TITLE="TWIN ROTOR DAIP DATA"
VARIABLES = DAIP,TOTF,TOTM
ZONE T = "GW = 13000 LB, WAGL = 25.0 FT", I=6, F=POINT
  50.00    94.05    288.66
  60.00    83.94    259.37
  70.00    73.00    227.47
  80.00    62.43    196.32
  90.00    52.82    167.46
 100.00    44.26    141.31
```

FIGURE D-38 EXAMPLE PERSONNEL OVERTURNING FORCE AND MOMENT GRAPHICS FILE FORMAT CREATED WITH THE INTERACTION PLANE ANALYSIS OPTION

LIST OF REFERENCES

D-1. Ferguson, S.W., and J.D. Kocurek, "Analysis and Recommendation of Separation Requirements for Rotorcraft Operation at Airports and Heliports," Systems Technology, Inc, Report TR-1224-1, September 1986.

D-2. Ferguson S.W., "Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight," U.S. Department of Transportation, Federal Aviation Administration, DOT/FAA/RD-90/16, December 1990.

D-3. Harris, D.J., and R.D. Simpson, "Technical Evaluation of the Rotor Downwash Flow Field of the XV-15 Tilt Rotor Research Aircraft," Naval Air Test Center, Technical Report No. SY-14R-83, July 1983.

D-4. Harris, D.J., and R.D. Simpson, "CH-53E Helicopter Downwash Evaluation. Final Report," Naval Air Test Center, Technical Report No. SY-89R-78, August 1978.

D-5. Harris, D.J., and R.D. Simpson, "CL-84 Tilt-Wing Vertical and Short Takeoff and Landing Downwash Evaluation. Final Report," Naval Air Test Center, Technical Report No. SY-52R-76, April 1976.

D-6. Hoerner, S.F., Fluid-Dynamic Drag, Published by Author, 1958.

APPENDIX E
ROTWASH PROGRAM FORTRAN 77 LISTINGS

ROTWASH program listings are presented in this appendix for the ROTWASH main program and its 24 subroutines. The listings are for a version of the program that is run on IBM PC/PC-compatible computers using MICROSOFT FORTRAN 77, Version 5.0. The tabular listing below indexes subroutine names and briefly describes functionality for user reference.

SUBROUTINE	FUNCTION
ROTWASH	Main Program Driver and Initialization
CLOUD	Calculates Particle Cloud Boundaries
DEVTX	Locates Disk Edge Vortex System and Calculates Induced Velocity Field
FREAD	Prompt/Validate for Floating Point Input Data
GDVTX	Locates Ground Vortex System and Calculates Induced Velocity Field
HAZARD	Driver Subroutine for Hazard Analysis
HIPVEL	Twin Rotor Overturning Forces and Moments
HOMCLS	Home Cursor and Clear Screen
HSVTX	Calculates Induced Velocity Field of a Horseshoe Vortex System
HWJVEL	Single Rotor Overturning Forces and Moments
INKEY	Menu Input Data Control
INPUT	Rotorcraft Characteristics Input Data Menu
INPUTV	Velocity Profile Status Menu
INPUTX	Ground/Disk Vortex Input Data Menu
IOFNSH	Close Disk I/O Files
IOINIT	File I/O Management Menu
IPVEL	Calculates Interaction Plane Velocity Profile
IREAD	Prompt/Validate for Integer Input Data
LEGAL	Check Validity of Input Data Selection Codes
LOCATE	Locate Cursor Position
MOMENT	Calculates Personnel Overturning Forces and Moments
PROPRM	Calculates Radial Wall Jet Velocity Profile
VLINE	Calculates Induced Velocity from a Line Vortex Field
WALJET	Defines Initial Wall Jet Position and Growth Parameters
WJVEL	Calculates Single Rotor Velocity Profile

```
C
C
        PROGRAM ROTWASH
C
C       ************************************************************
C       ROTORCRAFT DOWNWASH HAZARD ANALYSIS PROGRAM
C
C       EMA
C       SAMUEL W. FERGUSON
C
C       1 APRIL 1993
C
C       PROGRAM VERSION 2.1
C
C       THIS PROGRAM WAS DEVELOPED USING MICROSOFT FORTRAN 77 FOR
C       THE DOS OPERATING SYSTEM.  CONSOLE DISPLAY CONTROL IS
C       PROVIDED WITH THIS PROGRAM IN SEVERAL SPECIAL SUBROUTINES.
C       ************************************************************
C
        PARAMETER(NUM = 10)
C
        CHARACTER*1 OKLIST(NUM)
        CHARACTER*1 KEY,KKEY,FLOW,VELHAZ,HAZTYP
        CHARACTER*1 ICONT(5)
        CHARACTER*1 TEMCHAR
        CHARACTER*12 PTSFIL(4)
        CHARACTER*50 COMM(2)
        REAL*4 KE
C
        DIMENSION CONT(9),CONTV(7),CONTX(8)
C
        COMMON /  CKEY/ KEY,KKEY
        COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
        COMMON /HELGEO/ H,DL,YSEP,WSPD,RADIUS,SHFTAN,DXO
        COMMON /INPUTC/ ICONT,COMM,PTSFIL
        COMMON /INPUTD/ CONT,CONTV,CONTX,YBDLAY
        COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
        COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
        DATA CONT/2.0,32.2,12.5,12475.0,13.0,37.5,0.0,1.0,0.0/
CH53E        DATA CONT/1.0,0.0,39.5,56000.0,5.0,600.0,0.0,0.975,0.0/
        DATA YBDLAY/1.5/
        DATA ICONT/'V','N','N','W','L'/
        DATA CONTV/59.3,1.0,10.0,50.0,10.0,100.0,0.0/
        DATA CONTX/733.0,7.0,50.0,200.0,0.0,20.0,100.0,0.0/
        DATA PTSFIL/'DFRC.PTS','DAIP.PTS','OTDFRC.PTS','OTDAIP.PTS'/
        DATA COMM/
     1 'XV-15 CHARACTERISTICS ARE USED AS INPUT DATA ',
     2 'GROSS WEIGHT MIGHT BE ONE OF THE COMMENT STRINGS  '/
C
        DATA OKLIST /'W','w','I','i','G','g','D','d','X','x'/
C
C       **************************************************************
C
C       ----------------------
C       INITIALIZE I/O SYSTEM
C       ----------------------
C
        CALL IOINIT
C
C       ------------------------------------
C       INITIALIZE MISCELLANEOUS CONSTANTS
C       ------------------------------------
```

```
C
      PI     = ACOS(-1.0)
      RHOSL  = 0.0023769
      FPSPKN = 1.687
      DRC    = 0.01745329252
C
   50 CONTINUE
C
      KEY = ' '
      KKEY= ' '
C
C     ---------------------------------------------
C     OBTAIN INPUT DATA PARAMETERS FROM STATUS SCREEN
C     ---------------------------------------------
C
      CALL INPUT
C
C     ----------------------------------------------
C     DEFINE PARAMETERS OBTAINED FROM SUBROUTINE INPUT
C     ----------------------------------------------
C
      ROTORS = CONT(1)
      YYSEP  = CONT(2)
      RADIUS = CONT(3)
      HELGW  = CONT(4)
      DWNLD  = CONT(5)
      HAGL   = CONT(6)
      SHFTAN = CONT(7)
      SIGPR  = CONT(8)
      WSPD   = CONT(9)
C
      VELHAZ = ICONT(1)
C
C     ------------------------------------------
C     ADJUST GEOMETRY IF SHAFT ANGLE > 0.0 DEGREES
C     ------------------------------------------
C
      RSHFT  = SHFTAN*DRC
      CSHFTA = COS(RSHFT)
      DXO    = HAGL*TAN(RSHFT)
C
C     ---------------------------------------------
C     NON-DIMENSIONALIZE SOME OF THE INPUT PARAMETERS
C     ---------------------------------------------
C
      H      = HAGL/RADIUS/CSHFTA
      YSEP   = YYSEP/2.0/RADIUS
      EFFGW  = HELGW*(1.0 + (DWNLD/100.0))
      DL     = EFFGW/ROTORS/PI/RADIUS**2
      RHO    = SIGPR*RHOSL
      RHOD2  = 0.5*RHO
C
C     -------------------------------------------------------------
C     SWITCHING CALLS HAZARD PROGRAM AND ALLOWS RETURN (IF DESIRED)
C     TO THE MAINLINE ROUTINE TO CHANGE ROTORCRAFT INPUT PARAMETERS
C     -------------------------------------------------------------
C
      IF(VELHAZ.EQ.'H')THEN
C
        KKEY = 'H'
        CALL HAZARD(HAZTYP)
C
        IF(KEY.EQ.'X')GOTO 999
```

```
        IF(FLOW.EQ.'X')GOTO 999
        IF(HAZTYP.EQ.'X')GOTO 999
        GOTO 50
C
      ELSE
C
        KKEY = 'V'
C
      END IF
C
C     -----------------------
C     SELECT FLOWFIELD OPTION
C     -----------------------
C
   10 CONTINUE
C
C     ----------------------------
C     HOME CURSOR AND CLEAR SCREEN
C     ----------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(3,1)
C
      WRITE(IOU1,11)
   11 FORMAT ( 20X,' SELECT TYPE OF FLOW TO BE ESTIMATED',///,
     1     20X,'WALL JET PROFILE,                TYPE <W>',/,
     2     20X,'INTERACTION PLANE PROFILE,       TYPE <I>',/,
     2     20X,'GROUND VORTEX,                   TYPE <G>',/,
     2     20X,'DISK VORTEX,                     TYPE <D>',/,
     3     20X,'TO EXIT PROGRAM,                 TYPE <X>',//)
C
C     --------------------------------------------
C     PROMPT FOR, OBTAIN, AND CHECK FOR LEGAL INPUT
C     --------------------------------------------
C
   40 CONTINUE
C
      WRITE(IOU1,'(23X,A,$)')
     1 ' ENTER DATA ENTRY CODE   ==> '
C
      READ(IOU1,'(A1)') FLOW
C
      IF(LEGAL(FLOW,IOU1,OKLIST,NUM).EQ.1)GOTO 40
C
C     -------------------------------------------------------
C     MAKE LEGAL LOWERCASE INPUTS UPPER CASE BEFORE BRANCHING
C     -------------------------------------------------------
C
      IF(FLOW.EQ.'w') FLOW = 'W'
      IF(FLOW.EQ.'i') FLOW = 'I'
      IF(FLOW.EQ.'g') FLOW = 'G'
      IF(FLOW.EQ.'d') FLOW = 'D'
      IF(FLOW.EQ.'x') FLOW = 'X'
C
C     ----------------------------
C     HOME CURSOR AND CLEAR SCREEN
C     ----------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
C
C     --------------------------------------------
```

```
C     BRANCH BASED ON CHOSEN OPTION, ALSO
C     CHECK NUMBER OF ROTORS TO LIMIT SOME OPTIONS
C     ------------------------------------------
C
      IF(FLOW.EQ.'X')GOTO 999
      IF(FLOW.EQ.'W')GOTO 12
C
      IF(FLOW.EQ.'I')THEN
        IF(ROTORS.GT.1.0)GOTO 12
        WRITE(IOU1,'(////,14X,A,$)')
     1  ' REQUIRES TWO ROTORS, TYPE <RETURN> TO CONTINUE '
        READ(IOU1,'(A1)') TEMCHAR
        GOTO 10
      ENDIF
C
      IF(FLOW.EQ.'G')THEN
        IF(ROTORS.LT.2.0)GOTO 1000
        WRITE(IOU1,'(////,14X,A,$)')
     1  ' REQUIRES ONE ROTOR, TYPE <RETURN> TO CONTINUE '
        READ(IOU1,'(A1)') TEMCHAR
        GOTO 10
      ENDIF
C
      IF(FLOW.EQ.'D')THEN
        IF(ROTORS.LT.2.0)GOTO 1000
        WRITE(IOU1,'(////,14X,A,$)')
     1  ' REQUIRES ONE ROTOR, TYPE <RETURN> TO CONTINUE '
        READ(IOU1,'(A1)') TEMCHAR
        GOTO 10
      ENDIF
C
      GOTO 10
C
   12 CONTINUE
C
C     *********************
C     RADIAL WALL JET FLOWS
C     *********************
C
C     -------------------------------------
C     ACCELERATED SLIPSTREAM MEAN VELOCITY
C     -------------------------------------
C
      UN = SQRT(2.0*DL/RHO)
C
C     ------------------------
C     GROUND EFFECT CORRECTION
C     ------------------------
C
      AKG = 1.0 - 0.9*EXP(-2.0*H)
C
C     ------------------------------------------
C     MEAN VELOCITY AT ROTOR DISK (RATIOED TO UN)
C     ------------------------------------------
C
      UB = AKG/2.0
C
C     ------------------------------
C     FIND INITIAL RADIUS OF WALL JET
C     ------------------------------
C
      CALL WALJET(H,UB,UN,UMB)
C
```

```
  500 CONTINUE
C
      IF(KEY.EQ.'X')GOTO 999
      IF(KEY.EQ.'N')GOTO 50
      IF(FLOW.EQ.'I')GOTO 700
C
  600 CONTINUE
C
C     ------------------------------------------
C     WALL JET REGION
C
C     OBTAIN INPUT DATA FOR THE WALL JET OPTION
C     ------------------------------------------
C
      CALL INPUTV(FLOW)
C
      RVZ    = (CONTV(1) - DXO)/RADIUS
      DELZ   =  CONTV(2)/RADIUS
      ZMAX   =  CONTV(3)/RADIUS
      BDLAYM =  YBDLAY/RADIUS
C
C     ------------------------------------------------------
C     GENERATE VELOCITY PROFILE AT RVZ IN WALL JET REGION
C     ------------------------------------------------------
C
      CALL WJVEL(H,UN,UMB,RVZ,RADIUS,WSPD,DELZ,ZMAX,DXO,BDLAYM)
C
      GOTO 500
C
  700 CONTINUE
C
C     ------------------------------------------
C     INTERACTION PLANE UPWASH DEFLECTION ZONE
C
C     OBTAIN INPUT DATA FOR THE IPLANE OPTION
C     ------------------------------------------
C
      CALL INPUTV(FLOW)
C
      XIP    = (CONTV(1) - DXO)/RADIUS
      DELZ   =  CONTV(2)/RADIUS
      ZMAX   =  CONTV(3)/RADIUS
      BDLAYM =  YBDLAY/RADIUS
C
C     -------------------------------------------------------
C     GENERATE VELOCITY PROFILE AT XIP IN INTERACTION PLANE
C     -------------------------------------------------------
C
      CALL IPVEL(H,UN,RADIUS,UMB,XIP,YSEP,WSPD,DELZ,ZMAX,DXO,BDLAYM)
C
      GOTO 500
C
 1100 CONTINUE
C
      IF(KEY.EQ.'X')GOTO 999
      IF(KEY.EQ.'N')GOTO 50
C
 1000 CONTINUE
C
C     **********************
C     HORSESHOE VORTEX FLOWS
C     **********************
C
```

```
C      ------------------------------------
C      OBTAIN INPUT DATA FOR VORTEX OPTIONS
C      ------------------------------------
C
       CALL INPUTX
C
       OMEGAR = CONTX(1)
       B      = CONTX(2)
       VF     = CONTX(3)
       XT     = CONTX(4)/RADIUS
       YT     = CONTX(5)/RADIUS
       DELZ   = CONTX(6)/RADIUS
       ZMAX   = CONTX(7)/RADIUS
C
       VF  = VF*FPSPKN
       AMU = VF/OMEGAR
       CT  = DL/RHO/OMEGAR**2
C
C      -------------------------
C      ITERATE TO GET INFLOW RATIO
C      -------------------------
C
       ALOLD = SQRT(CT/2.0)
C
       DO 1300 ITER=1,100
C
       ALNEW  = CT/2.0/SQRT(ALOLD**2 + AMU**2)
C
       IF(ABS(ALNEW - ALOLD).LE.1.0E-05)GOTO 1301
C
       ALOLD = ALNEW
C
  1300 CONTINUE
C
C      ----------------------------
C      HOME CURSOR AND CLEAR SCREEN
C      ----------------------------
C
       ICD = 0
       CALL HOMCLS(ICD)
       CALL LOCATE(5,1)
C
       WRITE(IOU1,20)
    20 FORMAT( '**************************************',/
     1          ,'ITERATIONS EXCEEDED FOR INFLOW RATIO',/
     2          ,'**************************************')
C
       STOP ' '
C
  1301 CONTINUE
C
       ALAMDA = ALNEW
       AMUS   = AMU/SQRT(CT/2.0)
       GAMT   = OMEGAR*RADIUS*2.0*PI*CT/B
       CHI    = ATAN(ALAMDA/AMU)/2.0
C
C      ------------------------------------------------------------
C      GAMWP IS FOR UNIFORM LOADING IN FORWARD FLIGHT.
C      0.625 FACTOR COMES FROM UNPUBLISHED FAA FLIGHT TEST DATA.
C      IF SETTLING ANGLE CHI <= 8.0 DEGREES, THEN USE GAMWP AS IS.
C      IF > 8.0 DEGREES, THEN REDUCE GAMWP BY THE LINEAR
C      RATE OF 6.5% PER DEGREE OF SETTLING ANGLE.  THE REDUCTION
C      IS A SIMPLE APPROXIMATION FOR THE NEAR TERM THAT IS BASED
```

```
C      ON AN ANALYSIS OF THE UNPUBLISHED FAA FLIGHT TEST DATA.
C      MODS MADE FEBRUARY 1993.
C      -------------------------------------------------------------
C
       KE     = 0.625
       GAMWP  = PI*RADIUS*OMEGAR**2*CT/VF/2.0/KE
C
       IF(CHI.LE.0.139616)THEN
         GAMW = GAMWP
       ELSE
         GAMW = GAMWP*(1.0 - (CHI - 0.139616)*0.065*57.3)
         IF(GAMW.LT.0.0) GAMW = 0.0
       ENDIF
C
       HOD = H/2.0
C
C      -----------------------------
C      HOME CURSOR AND CLEAR SCREEN
C      -----------------------------
C
       ICD = 0
       CALL HOMCLS(ICD)
       CALL LOCATE(3,1)
C
       IF(FLOW.EQ.'D')GOTO 1200
C
C      --------------
C      GROUND VORTEX
C      --------------
C
       WRITE(IOU1,1001) HOD,AMUS,AMU
  1001 FORMAT( 18X,'ROTOR HEIGHT ABOVE GROUND H/D  ',2X,F8.4,/
     1        ,18X,'ADVANCE RATIO MU-STAR          ',2X,F8.4,/
     2        ,18X,'ADVANCE RATIO MU               ',2X,F8.4,//)
C
C      -------------------------------------------------------------
C      THE VALUE INPUT HERE REQUIRES USE OF THE CHART IN FIGURE 18
C      OF THE ACCOMPANYING DOCUMENTATION FOR THE GROUND VORTEX
C      -------------------------------------------------------------
C
    30 CONTINUE
C
       WRITE(IOU1,31)
    31 FORMAT( 18X,'ENTER GROUND VORTEX STRENGTH RATIO',/,
     1     25X,'(SEE FIGURE 18)              ==> '$)
C
       READ(IOU1,*,ERR=30) GAMG
C
       IF(GAMG.LT.0.0) GAMG = 0.0
C
C      ------------------
C      CONTINUE ANALYSIS
C      ------------------
C
       GAMG = GAMG*GAMT
C
       CALL GDVTX(H,RADIUS,AMU,CT,GAMG,XT,YT,DELZ,ZMAX)
C
       GOTO 1100
C
  1200 CONTINUE
C
C      ------------
```

```
C      DISK VORTEX
C      ------------
C
       CALL DEVTX(H,RADIUS,GAMW,CHI,XT,YT,DELZ,ZMAX)
C
       GOTO 1100
C
C      --------------------
C      NORMAL PROGRAM EXIT
C      --------------------
C
   999 CONTINUE
C
       END
C
```

```
C
C
      SUBROUTINE CLOUD(UN,UMB)
C
C     ****************************************************************
C     SUBROUTINE CLOUD
C
C     THIS SUBROUTINE MAKES THE CALCULATIONS REQUIRED IN ESTIMATING
C     THE PARTICLE CLOUD BOUNDARIES ( NO DENSITIES ) FOR SINGLE AND
C     TWIN ROTOR CONFIGURATIONS
C     ****************************************************************
C
      CHARACTER*1 KEY,KKEY
      CHARACTER*1 ICONT(5)
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CLOUDK/ QSMAX
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /HELGEO/ H,DL,YSEP,WSPD,RADIUS,SHFTAN,DXO
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ****************************************************************
C
C     ----------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ----------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(3,1)
C
C     -----------------------------------
C     READ IN THE TERRAIN FACTOR CONSTANT
C     (SEE FIGURE 30 OF USER'S GUIDE)
C     -----------------------------------
C
   10 CONTINUE
C
      WRITE(IOU1,20)
   20 FORMAT( 15X,'ENTER TERRAIN EROSION FACTOR (-ND-) ==> ',$)
C
      READ(IOU1,*,ERR=10) XKT
C
C     -------------------------
C     VALIDATE REAL INPUT VALUE
C     -------------------------
C
      IF(XKT.LE.0.0.OR.XKT.GT.500.0)GOTO 10
C
C     -------------------------------
C     DEFINE CLOUD BOUNDARY CONSTANTS
C     -------------------------------
C
      XKT  = SQRT(XKT)
C
      QSMX = RHOD2*((SQRT(QSMAX)*UN)**2)
      ERC  = -0.437
      XUM  = (UMB*UN)**2
      XCU  = CU*CU
```

```
      C1   = 1.0
      C2   = 2.2
C
C     ----------------------------------------
C     SINGLE ROTOR CLOUD BOUNDARY CALCULATIONS
C     ----------------------------------------
C
      RCR  = RADIUS*((XKT/(C1*RHOD2*XUM*XCU))**ERC)
      RVR  = 0.785*RCR
      ZVR  = 0.329*RCR
      RCVR = RCR - RVR
      AR   = (2.0/PI)*ALOC(ZVR/RCVR)
      PHIR = (PI/2.0)*ALOG(RCVR)/ALOG(ZVR/RCVR)
      AXLV = AR*((-PI/2.0) + PHIR)
      XLV  = EXP(AXLV)
      HCR  = XLV + ZVR
C
C     ---------------------------------------
C     INITIALIZE INTERACTION PLANE BOUNDARIES
C     ---------------------------------------
C
      RCI = 0.0
      RVI = 0.0
      ZVI = 0.0
      HCI = 0.0
      IF(YSEP.LE.0.1)GOTO 30
C
C     ---------------------------------------------
C     INTERACTION PLANE CLOUD BOUNDARY CALCULATIONS
C     ---------------------------------------------
C
      RCI  = RADIUS*((XKT/(C2*RHOD2*XUM*XCU))**ERC)
      RVI  = 0.785*RCI
      ZVI  = 0.329*RCI
      RCVR = RCI - RVI
      AR   = (2.0/PI)*ALOG(ZVI/RCVR)
      PHIR = (PI/2.0)*ALOG(RCVR)/ALOG(ZVI/RCVR)
      AXLV = AR*((-PI/2.0) + PHIR)
      XLV  = EXP(AXLV)
      HCI  = XLV + ZVI
C
   30 CONTINUE
C
C     --------------------------
C     PRINTOUT OF BOUNDARY LIMITS
C     --------------------------
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
C     --------------------------------------------
C     WRITE "40 FORMAT" IF OUTPUT TO GRAPHICS FILE
C     --------------------------------------------
C
      IF(IOU6.EQ.6) WRITE(IOU6,40) COMM(1),COMM(2)
   40 FORMAT( 10X,A50,/,10X,A50,//)
C
      WRITE(IOU6,50)
   50 FORMAT( //,
     1        20X,'       SUMMARY OF CLOUD BOUNDARIES',//,
     2        20X,'  RC AND RV ARE FROM ROTOR CENTER (FT)',//,
     3        20X,' RC ',7X,' RV ',7X,' ZV ',7X,' HC ',/)
C
      WRITE(IOU6,60) RCR,RVR,ZVR,HCR
```

```
   60 FORMAT( 13X,'SR',F10.1,3F11.1)
C
      WRITE(IOU6,70) RCI,RVI,ZVI,HCI
   70 FORMAT( 13X,'IP',F10.1,3F11.1)
C
      WRITE(IOU6,80) QSMX
   80 FORMAT( /,12X,' QSMAX =',F7.1,' PSF',//)
C
C     ------------------------------
C     DECIDE NEXT OPTION WITH INKEY
C     ------------------------------
C
      CALL INKEY
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE DEVTX(H,RADIUS,GAMW,CHI,XT,YT,DELZ,ZMAX)
C
C     ************************************************************
C     SUBROUTINE DEVTX
C
C     THIS SUBROUTINE LOCATES THE DISK EDGE VORTEX SYSTEM, AND
C     DIRECTS THE CALCULATION OF ITS INDUCED VELOCITY FIELD
C     ************************************************************
C
      CHARACTER*1 TEMCHAR
      CHARACTER*1 KEY,KKEY
      CHARACTER*1 ICONT(5)
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CHSVTX/ XL1,YL1,ZL1,XL2,YL2,ZL2,XL3,YL3,ZL3,
     1                XR1,YR1,ZR1,XR2,YR2,ZR2,XR3,YR3,ZR3
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ************************************************************
C
C     ----------------------------------------------------------
C     ASSUME HORSESHOE SHAPE - ASSIGN LEFT AND RIGHT CORNERS
C     ----------------------------------------------------------
C
      XL1 =  0.0
      YL1 = -1.0
      ZL1 = H
C
      XR1 = 0.0
      YR1 = 1.0
      ZR1 = H
C
C     ----------------------------------------------
C     SET UP DIRECTION POINTERS FOR TRAILER ELEMENTS
C     POINT 2 IS AT GROUND IMPINGEMENT
C     ----------------------------------------------
C
      XL2 = XL1 + H/TAN(CHI)
      YL2 = YL1
      ZL2 = 0.0
C
      XR2 = XR1 + H/TAN(CHI)
      YR2 = YR1
      ZR2 = 0.0
C
C     ----------------------------------------------
C     POINT THREE EXTENDS TRAILER PARALLEL TO GROUND
C     ----------------------------------------------
C
      XL3 = XL2 + 1.0
      YL3 = YL2
      ZL3 = ZL2
C
      XR3 = XR2 + 1.0
      YR3 = YR2
      ZR3 = ZR2
C
```

```
      XT = XT*RADIUS
      YT = YT*RADIUS
C
C     ------------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ------------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(4,1)
C
C     ------------------
C     WRITE OUTPUT HEADER
C     ------------------
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      WRITE(IOU6,1000) XT,YT
 1000 FORMAT( 21X,'DISK VORTEX VELOCITY PROFILE DATA',
     1 ///,14X,' X-LOCATION (XT)          = ',2X,F8.2,2X,'FT',
     2   /,14X,' Y-LOCATION (YT)          = ',2X,F8.2,2X,'FT',/)
C
C     -------------------------------------
C     GAMW TO METRIC UNITS OF METERS**2/SEC
C     -------------------------------------
C
      GAMWME = GAMW*0.092903
C
C     -----------------------------------------------------------
C     5-METER INITIAL CIRCULATION BASED ON 0.1D OR 0.2R CORE SIZE
C     5-METERS = 16.4042 FEET
C     -----------------------------------------------------------
C
      RCD5M  = 0.2*RADIUS/16.4042
      GAMW5M = GAMWME*(1.0 - RCD5M*ATAN(1.0/RCD5M))
C
      WRITE(IOU6,1001) GAMW,GAMWME,GAMW5M
 1001 FORMAT( 15X,'VORTEX CIRCULATION       = ',F10.2,2X,'FT**2/SEC',/
     1         15X,'VORTEX CIRCULATION       = ',F10.2,2X,'M**2/SEC',/
     2         15X,'5-M INITIAL CIRCULATION = ',F10.2,2X,'M**2/SEC')
C
      CHID = CHI*180.0/PI
C
      WRITE(IOU6,1005) CHID
 1005 FORMAT( 15X,'SETTLING ANGLE           = ',F10.2,2X,'DEG',////)
C
      WRITE(IOU1,'(23X,A,$)')
     1  ' PRESS <RETURN> TO CONTINUE  '
C
      READ(IOU1,'(A1)') TEMCHAR
C
      CALL HOMCLS(ICD)
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 14X,A50,/,10X,A50,//)
C
      WRITE(IOU6,1100)
 1100 FORMAT( 12X,'HEIGHT',8X,'MEAN VELOCITY',5X,'MEAN Q',/,
     1      '0',12X,'(FT)',8X,'(FPS)',6X,'(KN)',5X,'(PSF)',/)
C
C     ---------------------------------------------
C     SET UP SWEEP OF Z AT SPECIFIED X,Y
C     DELZ AND ZMAX COME FROM A MAINLINE STATUS MENU
```

```
C     --------------------------------------------------
C
      XT    = XT/RADIUS
      YT    = YT/RADIUS
      NPTS  = IFIX(ZMAX/DELZ) + 2
      LINES = 0
C
      DO 200 I=1,NPTS
C
      LINES = LINES + 4
      ZT    = (I - 1)*DELZ
C
      CALL HSVTX(XT,YT,ZT,VXF,VYF,VZF,GAMW,RADIUS)
C
      ZZ  = ZT*RADIUS
      VTF = SQRT(VXF**2 + VYF**2 + VZF**2)
      VXK = VXF/FPSPKN
      VYK = VYF/FPSPKN
      VZK = VZF/FPSPKN
      VTK = VTF/FPSPKN
C
      QX  = RHOD2*VXF**2
      QY  = RHOD2*VYF**2
      QZ  = RHOD2*VZF**2
      QT  = RHOD2*VTF**2
C
C     -----------------------------------------
C     KEEP OUTPUT PAGE LENGTH TO SIZE OF SCREEN
C     -----------------------------------------
C
      IF(IOU6.EQ.IOU1)THEN
        IF(LINES.LE.12)GOTO 100
        LINES = 4
        CALL INKEY
        IF(KEY.NE.'C')GOTO 999
        WRITE(IOU6,1100)
      ENDIF
C
  100 CONTINUE
C
C     ------------------------------
C     REPORT X COMPONENT OF VELOCITY
C     ------------------------------
C
      WRITE(IOU6,1101) ZZ,VXF,VXK,QX
 1101 FORMAT( 9X,F8.2,2X,'X',3F10.3)
C
C     ------------------------------
C     REPORT Y COMPONENT OF VELOCITY
C     ------------------------------
C
      WRITE(IOU6,1102) VYF,VYK,QY
 1102 FORMAT( 19X,'Y',3F10.3)
C
C     ------------------------------
C     REPORT Z COMPONENT OF VELOCITY
C     ------------------------------
C
      WRITE(IOU6,1103) VZF,VZK,QZ
 1103 FORMAT( 19X,'Z',3F10.3)
C
C     ---------------------
C     REPORT TOTAL VELOCITY
```

```
C       ----------------------
C
        WRITE(IOU6,1104) VTF,VTK,QT
 1104   FORMAT( 19X,'T',3F10.3)
C
  200   CONTINUE
C
        CALL INKEY
C
  999   CONTINUE
C
        RETURN
        END
C
```

```
C
C
      SUBROUTINE FREAD(IOU1,PROMPT,VALUE,CONST)
C
C     ***********************************************
C     SUBROUTINE FREAD PROMPTS USER FOR A FLOATING
C     POINT DATA ENTRY AND CHECKS VALIDITY OF ENTRY
C     ***********************************************
C
      PARAMETER(LAST=50)
C
      CHARACTER*50 PROMPT,SHOWIT
      CHARACTER*15 ENTRY,BLANK
C
      DATA BLANK /'               '/
C
C     ***********************************************
C
C     -----------------------------------------------------
C     PROMPT USER FOR SCALED FLOATING POINT ENTRY.
C     FIND POSITION OF LAST NON-BLANK CHARACTER IN PROMPT,
C     THEN STORE RIGHT JUSTIFIED IN SHOWIT.
C     -----------------------------------------------------
C
      N = LAST + 1
C
   10 IF(N.EQ.1)GOTO 20
C
      N = N - 1
C
      IF(PROMPT(N:N).EQ.' ')GOTO 10
C
   20 JS = LAST - N
C
      WRITE(SHOWIT,'(50A1)') (' ',J=1,JS),(PROMPT(I:I),I=1,N)
C
C     ------------------------------
C     NOW ASK USER FOR DATA ENTRY
C     ------------------------------
C
   30 WRITE(IOU1,'(/,1X,A,G13.6)') SHOWIT,VALUE*CONST
C
      WRITE(IOU1,'(/,8X,A,$)')
     1 ' ENTER NEW VALUE OR <RETURN> TO LEAVE AS IS    ==> '
C
      READ(IOU1,'(A)') ENTRY
C
      IF(ENTRY.EQ.BLANK)RETURN
C
      READ(ENTRY,'(BN,F15.0)',ERR=30) TEMP
C
C     ------------------------------------
C     CONSTANT CAN BE USED TO SCALE OR
C     OR CONVERT UNITS OF AN INPUT VALUE
C     ------------------------------------
C
      VALUE = TEMP/CONST
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE GDVTX(H,RADIUS,AMU,CT,GAMG,XT,YT,DELZ,ZMAX)
C
C     ************************************************************
C     SUBROUTINE GDVTX
C
C     THIS SUBROUTINE LOCATES THE GROUND VORTEX BASED ON THE
C     EXPERIMENTS BY SUN AND CURTIS (PRINCETON UNIV.), AND THEN
C     DIRECTS THE CALCULATION OF ITS INDUCED VELOCITY FIELD
C
C     THE OUTPUT FROM THIS SUBROUTINE SHOULD BE USED CAREFULLY
C     FOR GROSS ESTIMATION PURPOSES ONLY
C     ************************************************************
C
      CHARACTER*1 ICONT(5)
      CHARACTER*1 TEMCHAR
      CHARACTER*1 KEY,KKEY
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CHSVTX/ XL1,YL1,ZL1,XL2,YL2,ZL2,XL3,YL3,ZL3,
     1                XR1,YR1,ZR1,XR2,YR2,ZR2,XR3,YR3,ZR3
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ************************************************************
C
      HOD    = H/2.0
      C1     = 1.0 + 1.2086*HOD**0.4374
      C2     = -0.2786*HOD**0.6757
      ZGV    = -10.0*AMU + 0.6
      XGV    = -(C1 + C2*(AMU/CT))**2
      XXGV   = XGV*RADIUS
      ZZGV   = ZGV*RADIUS
C
C     -------------------------------------------------------
C     ASSUME HORSESHOE SHAPE - ASSIGN LEFT AND RIGHT CORNERS
C     -------------------------------------------------------
C
      XL1 = XGV
      YL1 = -1.0
      ZL1 = ZGV
C
      XR1 = XGV
      YR1 = 1.0
      ZR1 = ZGV
C
C     ---------------------------------------------
C     SET UP DIRECTION POINTERS FOR TRAILER ELEMENTS
C     ---------------------------------------------
C
      XL2 = XL1 + 1.0
      YL2 = YL1
      ZL2 = ZL1
C
      XR2 = XR1 + 1.0
      YR2 = YR1
      ZR2 = ZR1
C
      XL3 = XL2 + 1.0
```

```
      YL3 = YL2
      ZL3 = ZL2
C
      XR3 = XR2 + 1.0
      YR3 = YR2
      ZR3 = ZR2
C
C     ---------------------------------------------------
C     WRITE OUT GROUND VORTEX POSITION/STRENGTH DATA
C     ---------------------------------------------------
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      WRITE(IOU6,1001) XXGV,ZZGV
 1001 FORMAT( //,24X,'GROUND VORTEX CORE POSITION',//,
     1 18X,'X-LOCATION (XXGV)          = ',1X,F8.2,2X,'FT',/
     2 18X,'Y-LOCATION (ZZGV)          = ',1X,F8.2,2X,'FT')
C
      WRITE(IOU6,1002) GAMG
 1002 FORMAT( /,18X,'GROUND VORTEX CIRCULATION = ',1X,
     1           F8.2,2X,'FT**2/SEC',//)
C
      WRITE(IOU1,'(23X,A,$)')
     1 ' PRESS <RETURN> TO CONTINUE '
C
      READ(IOU1,'(A1)') TEMCHAR
C
      ICD = 0
      CALL HOMCLS(ICD)
C
C     --------------------
C     WRITE OUTPUT HEADER
C     --------------------
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 14X,A50,/,10X,A50,//)
C
      WRITE(IOU6,1100)
 1100 FORMAT( 12X,'HEIGHT',8X,'MEAN VELOCITY',5X,'MEAN Q',/,
     1        '0',12X,'(FT)',8X,'(FPS)',6X,'(KN)',5X,'(PSF)',/)
C
C     ---------------------------------------------------
C     SET UP SWEEP OF Z AT SPECIFIED X,Y
C     DELZ AND ZMAX COME FROM MAINLINE STATUS SCREEN
C     ---------------------------------------------------
C
      NPTS  = IFIX(ZMAX/DELZ) + 2
      LINES = 0
C
      DO 200 I=1,NPTS
C
      LINES = LINES + 4
      ZT    = (I - 1)*DELZ
C
      CALL HSVTX(XT,YT,ZT,VXF,VYF,VZF,GAMG,RADIUS)
C
      ZZ  = ZT*RADIUS
      VTF = SQRT(VXF**2 + VYF**2 + VZF**2)
      VXK = VXF/FPSPKN
      VYK = VYF/FPSPKN
      VZK = VZF/FPSPKN
      VTK = VTF/FPSPKN
C
```

```
          QX   = RHOD2*VXF**2
          QY   = RHOD2*VYF**2
          QZ   = RHOD2*VZF**2
          QT   = RHOD2*VTF**2
C
          IF  (IOU6.EQ.IOU1)THEN
            IF(LINES.LE.12)GOTO 100
            LINES = 4
            CALL INKEY
            IF(KEY.NE.'C')GOTO 999
            WRITE(IOU6,1100)
          ENDIF
C
      100 CONTINUE
C
C         ------------------------------
C         REPORT X COMPONENT OF VELOCITY
C         ------------------------------
C
          WRITE(IOU6,1101) ZZ,VXF,VXK,QX
     1101 FORMAT( 9X,F8.2,2X,'X',3F10.3)
C
C         ------------------------------
C         REPORT Y COMPONENT OF VELOCITY
C         ------------------------------
C
          WRITE(IOU6,1102) VYF,VYK,QY
     1102 FORMAT( 19X,'Y',3F10.3)
C
C         ------------------------------
C         REPORT Z COMPONENT OF VELOCITY
C         ------------------------------
C
          WRITE(IOU6,1103) VZF,VZK,QZ
     1103 FORMAT( 19X,'Z',3F10.3)
C
C         ---------------------
C         REPORT TOTAL VELOCITY
C         ---------------------
C
          WRITE(IOU6,1104) VTF,VTK,QT
     1104 FORMAT( 19X,'T',3F10.3)
C
      200 CONTINUE
C
          CALL INKEY
C
      999 CONTINUE
C
          RETURN
          END
C
```

```
C
C
      SUBROUTINE HAZARD(HAZTYP)
C
C     ****************************************************
C     SUBROUTINE HAZARD IS THE MAINLINE DRIVER FOR THE
C     CALCULATION OF SPECIFIC HAZARDS
C     ****************************************************
C
      PARAMETER(NUM1 =  6)
      PARAMETER(NUM2 = 15)
      PARAMETER(NUM3 =  4)
      PARAMETER(NUM4 =  4)
C
      CHARACTER*1 OKLST1(NUM1)
      CHARACTER*1 OKLST2(NUM2)
      CHARACTER*1 OKLST3(NUM3)
      CHARACTER*1 OKLST4(NUM4)
C
      CHARACTER*1 KEY,KKEY,HAZTYP,HUMTYP
      CHARACTER*1 CHDOL,CVALUE
      CHARACTER*1 ICONT(5)
      CHARACTER*12 PTSFIL(4)
      CHARACTER*12 TMPFIL
      CHARACTER*50 COMM(2)
      CHARACTER*50 PROMPT
C
      DIMENSION CONT(9),CONTV(7),CONTX(8)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /HELGEO/ H,DL,YSEP,WSPD,RADIUS,SHFTAN,DXO
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /INPUTD/ CONT,CONTV,CONTX,YBDLAY
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ****************************************************
C
      DATA OKLST1 /'C','c','M','m','X','x'/
      DATA OKLST2 /' ','A','a','B','b','C','c','D','d',
     1             'E','e','F','f','G','g'/
      DATA OKLST3 /'W','w','I','i'/
      DATA OKLST4 /'L','l','S','s'/
C
C     ---------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ---------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(4,1)
C
C     -------------------------------------
C     DETERMINE THE TYPE OF HAZARD ANALYSIS
C     OPTION THAT WILL BE EXECUTED
C     -------------------------------------
C
      WRITE(IOU1,10)
   10 FORMAT ( 25X,' SELECT TYPE OF HAZARD',///,
     1      18X,'OVERTURNING FORCE/MOMENT,    TYPE <M>',/,
     2      18X,'PARTICULATE CLOUDS,          TYPE <C>',/,
     3      18X,'TO EXIT PROGRAM,             TYPE <X>',//)
```

```
C
C     ----------------------------------------------
C     INQUIRE, OBTAIN, AND CHECK FOR VALID MENU CODE
C     ----------------------------------------------
C
   11 CONTINUE
C
      WRITE(IOU1,'(23X,A,$)') ' ENTER HAZARD CODE ==> '
C
      READ(IOU1,'(A1)') HAZTYP
C
      IF(LEGAL(HAZTYP,IOU1,OKLST1,NUM1).EQ.1)GOTO 11
C
C     ----------------------------------------
C     CORRECT LOWER CASE LETTERS TO UPPER CASE
C     TO USE AS VALID FLAGS IN PARENT SUBROUTINE
C     ----------------------------------------
C
      IF(HAZTYP.EQ.'c') HAZTYP = 'C'
      IF(HAZTYP.EQ.'m') HAZTYP = 'M'
      IF(HAZTYP.EQ.'x') HAZTYP = 'X'
C
C     ---------------------------
C     BRANCH IF EXIT OPTION CHOSEN
C     ---------------------------
C
      IF(HAZTYP.EQ.'M')GOTO 18
      IF(HAZTYP.EQ.'C')GOTO 18
      IF(HAZTYP.EQ.'X')GOTO 999
C
      GOTO 11
C
   18 CONTINUE
C
C     *********************************
C     RADIAL WALL JET FLOW INFORMATION
C     *********************************
C
C     ------------------------------------
C     ACCELERATED SLIPSTREAM MEAN VELOCITY
C     ------------------------------------
C
      UN = SQRT(2.0*DL/RHO)
C
C     ------------------------
C     GROUND EFFECT CORRECTION
C     ------------------------
C
      AKG = 1.0 - 0.9*EXP(-2.0*H)
C
C     ------------------------------------------
C     MEAN VELOCITY AT ROTOR DISK (RATIOED TO UN)
C     ------------------------------------------
C
      UB = AKG/2.0
C
C     ------------------------------
C     FIND INITIAL RADIUS OF WALL JET
C     ------------------------------
C
      CALL WALJET(H,UB,UN,UMB)
C
  500 CONTINUE
```

```
C
      IF(KEY.EQ.'X')GOTO 999
      IF(KEY.EQ.'N')GOTO 999
C
C     -----------------------------
C     BRANCH IF CLOUD OPTION CHOSEN
C     -----------------------------
C
      IF(HAZTYP.EQ.'C')GOTO 800
C
C     ***************************
C     OVERTURNING FORCES/MOMENTS
C     ***************************
C
C     ---------------------------------------------
C     DETERMINE:
C
C        1. THE AXIS ALONG WHICH THE OVERTURNING
C           FORCES/MOMENTS WILL BE CALCULATED
C
C        2. THE SIZE OF THE PERSON AFFECTED
C
C        3. THE DISTANCES AT WHICH THE OVERTURNING
C           FORCES/MOMENTS WILL BE CALCULATED
C     ---------------------------------------------
C
   20 CONTINUE
C
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(2,1)
C
      WRITE(IOU1,12)
   12 FORMAT( 20X,' OVERTURNING FORCE/MOMENT DATA MENU',//,
     1   10X,'CODE           PARAMETER                        VALUE',
     2        '    UNITS',/)
C
C     ---------------------------------------------------
C     PRINT OUT MENU VARIABLES AS BASED ON THE WALL JET
C     OPTION OR INTERACTION PLANE OPTION SWITCH SETTING
C     ---------------------------------------------------
C
      IF(ICONT(4).EQ.'W')THEN
C
         WRITE(IOU1,14)  ICONT(4),ICONT(5),PTSFIL(3),
     1                   CONTV(4),CONTV(5),CONTV(6),YBDLAY
C
      ELSE
C
         WRITE(IOU1,14)  ICONT(4),ICONT(5),PTSFIL(4),
     1                   CONTV(4),CONTV(5),CONTV(6),YBDLAY
C
      ENDIF
C
   14 FORMAT( 11X,'A    <W>ALL JET OR <I>NTERACTION PLANE',5X,A2,/,
     1  11X,'B    <L>ARGE OR <S>MALL PERSON         ',5X,A2,/,
     2  11X,'C    DATA OUTPUT FILENAME              ',2X,A12,/,
     3  11X,'                                   ',/,
     4  11X,'D    INITIAL STATION POSITION      ',5X,F7.2,4X,'FT',/,
     5  11X,'E    HORIZONTAL INCREMENT          ',5X,F7.2,4X,'FT',/,
     6  11X,'F    MAXIMUM STATION POSITION      ',5X,F7.2,4X,'FT',/,
     6  11X,'G    MINIMUM BOUNDARY LAYER HEIGHT ',5X,F7.2,4X,'FT',//)
C
```

```
C     ------------------------------------------------
C     PROMPT FOR, OBTAIN, AND CHECK FOR LEGAL INPUT DATA
C     ------------------------------------------------
C
   16 CONTINUE
C
      WRITE(IOU1,'(8X,A,$)')
     1' ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==> '
C
      READ(IOU1,'(A1)') CHDOL
C
      IF(LEGAL(CHDOL,IOU1,OKLST2,NUM2).EQ.1)GOTO 16
C
C     ----------------------------------------
C     DIRECT OPTIONS BASED ON CHOICE FOR "CHDOL"
C     ----------------------------------------
C
      IF(CHDOL.EQ.' ')GOTO 30
C
C     --------------------------
C     CHOOSE WALJET OR IPLANE OPTION
C     --------------------------
C
      IF(CHDOL.EQ.'A'.OR.CHDOL.EQ.'a')THEN
C
   40   CONTINUE
C
        WRITE(IOU1,'(/,35X,A,1X,A2/)') ' ANALYSIS TYPE = ',ICONT(4)
        WRITE(IOU1,'(37X,A,$)') ' ENTER NEW CODE   ==> '
        READ(IOU1,'(A1)') CVALUE
C
        IF(LEGAL(CVALUE,IOU1,OKLST3,NUM3).EQ.1)GOTO 40
C
        ICONT(4) = CVALUE
        IF(ICONT(4).EQ.'w') ICONT(4) = 'W'
        IF(ICONT(4).EQ.'i') ICONT(4) = 'I'
        GOTO 20
C
      ENDIF
C
C     --------------------------
C     CHOOSE LARGE OR SMALL PERSON
C     --------------------------
C
      IF(CHDOL.EQ.'B'.OR.CHDOL.EQ.'b')THEN
C
   41   CONTINUE
C
        WRITE(IOU1,'(/,35X,A,1X,A2/)') ' PERSON TYPE = ',ICONT(5)
        WRITE(IOU1,'(37X,A,$)') ' ENTER NEW CODE   ==> '
        READ(IOU1,'(A1)') CVALUE
C
        IF(LEGAL(CVALUE,IOU1,OKLST4,NUM4).EQ.1)GOTO 41
C
        ICONT(5) = CVALUE
        IF(ICONT(5).EQ.'l') ICONT(5) = 'L'
        IF(ICONT(5).EQ.'s') ICONT(5) = 'S'
        GOTO 20
C
      ENDIF
C
C     ------------------------
C     CHOOSE GRAPHICS FILENAME
```

```
C       ------------------------
C
        IF(CHDOL.EQ.'C'.OR.CHDOL.EQ.'c')THEN
C
          IF(ICONT(4).EQ.'W')THEN
            WRITE(IOU1,'(/,25X,A,1X,A12/)')
     1           ' FILENAME = ',PTSFIL(3)
          ELSE
            WRITE(IOU1,'(/,25X,A,1X,A12/)')
     1           ' FILENAME = ',PTSFIL(4)
          ENDIF
C
          WRITE(IOU1,'(20X,A,$)')
     1 ' ENTER NEW FILENAME (xxxxxxxx.xxx) ==> '
C
          READ(IOU1,'(A12)') TMPFIL
C
          IF(ICONT(4).EQ.'W') PTSFIL(3) = TMPFIL
          IF(ICONT(4).EQ.'I') PTSFIL(4) = TMPFIL
          GOTO 20
C
        ENDIF
C
C       --------------------------------
C       CHOOSE INITIAL STATION POSITION
C       --------------------------------
C
        IF(CHDOL.EQ.'D'.OR.CHDOL.EQ.'d')THEN
C
          PROMPT = 'INITIAL STATION POSITION = '
          CALL FREAD(IOU1,PROMPT,CONTV(4),1.0)
C
          IF(CONTV(4).LT.0.0) CONTV(4) = 0.0
          GOTO 20
C
        ENDIF
C
C       ----------------------------
C       CHOOSE HORIZONTAL INCREMENT
C       ----------------------------
C
        IF(CHDOL.EQ.'E'.OR.CHDOL.EQ.'e')THEN
C
          PROMPT = 'HORIZONTAL INCREMENT = '
          CALL FREAD(IOU1,PROMPT,CONTV(5),1.0)
C
          IF(CONTV(5).LT.0.0) CONTV(5) = 0.0
          GOTO 20
C
        ENDIF
C
C       ----------------------------
C       CHOOSE HORIZONTAL INCREMENT
C       ----------------------------
C
        IF(CHDOL.EQ.'F'.OR.CHDOL.EQ.'f')THEN
C
          PROMPT = 'MAXIMUM STATION POSITION = '
          CALL FREAD(IOU1,PROMPT,CONTV(6),1.0)
C
          IF(CONTV(6).LT.CONTV(4)) CONTV(6) = CONTV(4)
          GOTO 20
C
```

```
          ENDIF
C
          IF(CHDOL.EQ.'G'.OR.CHDOL.EQ.'g')THEN
C
             PROMPT = 'MINIMUM BOUNDARY LAYER HEIGHT = '
             CALL FREAD(IOU1,PROMPT,YBDLAY,1.0)
C
             IF(YBDLAY.LT.0.0) YBDLAY = 0.0
             GOTO 20
C
          ENDIF
C
          GOTO 20
C
       30 CONTINUE
C
          ICD = 0
          CALL HOMCLS(ICD)
C
          IF(ICONT(4).EQ.'I')GOTO 700
C
      600 CONTINUE
C
C         ---------------------------------
C         WALL JET REGION
C
C         OBTAIN DATA FOR THE HWJVEL OPTION
C         ---------------------------------
C
          RVZ    = (CONTV(4) - DXO)/RADIUS
          DELH   = CONTV(5)
          HMAX   = CONTV(6)
          HUMTYP = ICONT(5)
          BDLAYM = YBDLAY/RADIUS
C
C         ---------------------------------------------------
C         GENERATE VELOCITY PROFILE AT RVZ IN WALL JET REGION
C         ---------------------------------------------------
C
          CALL
HWJVEL(H,UN,UMB,RVZ,RADIUS,WSPD,DELH,HMAX,HUMTYP,DXO,BDLAYM)
C
          GOTO 500
C
      700 CONTINUE
C
C         ----------------------------------------
C         INTERACTION PLANE UPWASH DEFLECTION ZONE
C
C         OBTAIN INPUT DATA FOR THE HIPVEL OPTION
C         ----------------------------------------
C
          XIP    = (CONTV(4) - DXO)/RADIUS
          DELH   = CONTV(5)
          HMAX   = CONTV(6)
          HUMTYP = ICONT(5)
          BDLAYM = YBDLAY/RADIUS
C
C         -----------------------------------------------------
C         GENERATE VELOCITY PROFILE AT XIP IN INTERACTION PLANE
C         -----------------------------------------------------
C
          CALL HIPVEL(H,UN,RADIUS,UMB,XIP,YSEP,WSPD,DELH,HMAX,
```

```
     *                  HUMTYP,DXO,BDLAYM)
C
      GOTO 500
C
  800 CONTINUE
C
C     ***************************************
C     CALCULATE PARTICULATE CLOUD BOUNDARIES
C     ***************************************
C
      CALL CLOUD(UN,UMB)
C
      GOTO 500
C
C     --------------------
C     NORMAL PROGRAM EXIT
C     --------------------
C
  999 CONTINUE
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE HIPVEL(H,UN,RADIUS,UMB,XIP,YSEP,WSPD,DELH,
     *                        HMAX,HUMTYP,DXO,BDLAYM)
C
C
***********************************************************************
C     SUBROUTINE HIPVEL GENERATES THE VELOCITY PROFILE AND THE FORCES
C     AND OVERTURNING MOMENTS FOR A HUMAN BEING ALONG THE INTERACTION
C     PLANE FOR THE TWIN ROTOR CASE
C
******  .. '***********************************************************
C
      CHARACTER*1 TEMCHAR
      CHARACTER*1 KEY,KKEY,HUMTYP
      CHARACTER*1 ICONT(5)
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /PERSON/ QP(12),DSET
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C
***********************************************************************
C
      ICD = 0
      CALL HOMCLS(ICD)
C
C     ---------------------------------------------------
C     INPUT FOR DELH AND HMAX COMES FROM INPUTV STATUS MENU
C     ---------------------------------------------------
C
      DSET = DELH
      IF(DSET.EQ.0.)DELH = HMAX
C
      DELH  = DELH/RADIUS
      HMAX  = HMAX/RADIUS
      NHPTS = IFIX((HMAX - XIP)/DELH) + 1
C
      IF(DSET.EQ.0.)GOTO 33
C
C     ---------------------------------------------
C     WRITE OUTPUT HEADER (FOR PLOT FILE, SEE BELOW)
C     ---------------------------------------------
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 10X,A50,/,10X,A50,//)
C
      WRITE(IOU6,1001)
 1001 FORMAT( 12X,' SUMMARY OF OVERTURNING FORCES AND MOMENTS',//,
     1          19X,'RADIUS',6X,'TOTF',6X,'TOTM',/,
     2          20X,'(FT)',7X,'(LB)',5X,'(FT-LB)',/)
   33 CONTINUE
C
C     -----------------------------------------------
C     WRITE OUT GRAPHICS FILES IF SWITCH IS SET BY USER
C     -----------------------------------------------
```

```
C
      IF(IGRAPH.EQ.1)THEN
C
C     ---------------------------------------
C     OPEN GRAPHICS FILE AND WRITE FILE HEADER
C     ---------------------------------------
C
      OPEN(IOU8,FILE=PTSFIL(4),STATUS='NEW',ERR=2000)
C
      WRITE(IOU8,83) COMM(1),COMM(2)
   83 FORMAT( 10X,A50,/,10X,A50,//)
C
      WRITE(IOU8,80)
   80 FORMAT( 1X,'TITLE="TWIN ROTOR DAIP DATA"')
C
      WRITE(IOU8,81)
   81 FORMAT( 1X,'VARIABLES = DAIP,TOTF,TOTM')
C
      WRITE(IOU8,88)
   88 FORMAT( 1X,'ZONE T = "GW = xxxxx LB, WAGL = xx FT",',
     *             ' I=x, F=POINT')
C
      ENDIF
C
C     ---------------------------------------------------
C     BEGIN LOOP INCREMENTING THE RADIAL POINTS AT WHICH
C     THE OVERTURNING MOMENT CALCULATIONS ARE MADE
C     -------------------------------------------------------
C
      DO 565 K = 1,NHPTS
C
C     ------------------------------------------
C     TF IS INTERACTION PLANE AMPLIFICATION FACTOR
C     (SEE NOTE IN IPVEL.FOR FOR VERSION 2.1)
C     ------------------------------------------
C
      TF = 1.65 - (0.65)*EXP(-0.5*XIP)
C
C     ---------------------------------------------------
C     GET PARAMETERS AT BASE RADIUS FOR 'BOUNDARY LAYER'
C     ---------------------------------------------------
C
      RIP0 = SQRT(XIP**2 + YSEP**2)
C
C     ---------------------------------------------------
C     'PROPRM' PROVIDES THE VELOCITY PROFILE PARAMETERS
C     OF A RADIAL WALL JET (WITHOUT INTERACTION PLANE)
C     ---------------------------------------------------
C
      CALL PROPRM(H,UMB,RIP0)
C
      ZIPB = ZB
      ZIPM = ZM
      ZIPH = ZH
C
      RIPM = SQRT(XIP**2 + (YSEP + ZIPM)**2)
C
      CALL PROPRM(H,UMB,RIPM)
C
      UMM = UM
C
C     -------------
C     OUTPUT HEADER
```

```
C      --------------
C
       IF(DSET.NE.0.)GOTO 78
C
       XXIP   = RADIUS*XIP
       XIPOUT = XXIP + DYO
C
       IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
       IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
C
       WRITE(IOU6,1000) XIPOUT
  1000 FORMAT( 2X,'TWIN ROTOR INTERACTION PLANE VELOCITY PROFILE',
      1           ' AT DISTANCE = ',F7.1,' FT',//)
C
       WRITE(IOU6,1002)
  1002 FORMAT( 3X,'HEIGHT',6X,'MEAN VELOCITY',7X,'PEAK VELOCITY',6X,
      1        'MEAN Q',4X,'PEAK Q',/,
      2        3X,'(FT)',7X,'(FPS)',6X,'(KN)',5X,'(FPS)',6X,'(KN)',5X,
      3        '(PSF)',5X,'(PSF)',/)
    78 CONTINUE
C
C      ----------------------------
C      'AN' IS ACTUALLY '= 1.0/7.0'
C      ----------------------------
C
       AN = 0.142857142
C
       DELZ = 0.5/RADIUS
       NPTS = 12
C
       DO 500 I = 1,NPTS
C
       ZIP = DELZ*(I - 1) + (0.25/RADIUS)
C
C      ----------------------------------------------
C      GET MAX WALL JET VELOCITY AT EFFECTIVE RADIUS
C      ----------------------------------------------
C
       RIP = SQRT(XIP**2 + (YSEP + ZIP)**2)
C
       CALL PROPRM(H,UMB,RIP)
C
       VN = UN
       VZ = UM
C
C      --------------------------- ---------------
C      INTERACTION PLANE 'BOUNDARY LAYER'
C
C      CODE MODIFIED IN MAY 1992 FOR USER SPECIFIED
C      MINIMUM BOUNDARY LAYER THICKNESS (BDLAYM)
C      ---------------------------------------------
C
       ZIP1 = BDLAYM
C
       IF(ZIP.LT.ZIPM.OR.ZIP.LT.ZIP1)THEN
C
               IF(ZIP1.LT.ZIPM)THEN
C
                 VZ = UMM*(ZIP/ZIPM)**AN
C
               ELSE
C
```

```
                    VZ = UMM*(ZIP/ZIP1)**AN
      C
                  ENDIF
      C
          ENDIF
      C
      C   --------------------------------
      C   DEVELOPED INTERACTION PLANE JET
      C   --------------------------------
      C
          VH = TF*VZ*XIP/RIP
          VV = TF*VZ*(YSEP + ZIP)/RIP
      C
          ZZ = ZIP*RADIUS
      C
      C   ------------------------------------------------
      C   MEAN HORIZONTAL VELOCITIES AND DYNAMIC PRESSURE
      C   ------------------------------------------------
      C
          VHMF = VH*UN
          VHMK = VHMF/FPSPKN
      C
      C   ----------------------------------------
      C   PEAK VELOCITIES (BOTH FT/SEC AND KNOTS)
      C
      C   EQUATION FOR VMFD3I UPDATED FROM 1st TO
      C   2nd ORDER POLYNOMIAL FOR VERSION 2.1
      C   ----------------------------------------
      C
          VMFD3I = 0.712887 + 0.304369*XIP - 0.018496*XIP*XIP
      C
          IF(VMFD3I.LT.1.2) VMFD3I = 1.2
      C
          VHPF = VMFD3I*VHMF
          VHPK = VHPF/FPSPKN
      C
      C   ---------------------------------------------------------
      C   THE EFFECT OF WIND IS TO ADD (DOWNWIND SIDE) OR SUBTRACT
      C   (UPWIND SIDE) 'XWK' TIMES THE AMBIENT WIND VELOCITY TO
      C   THE HORIZONTAL PROFILE VELOCITY (EMPIRICAL, CH-53E BASED)
      C   ---------------------------------------------------------
      C
          XKW = (-0.5*H) + 2.5
      C
          IF(XKW.LT.1.0)XKW = 1.0
      C
          WSPD2 = WSPD*XKW
          VHMK  = VHMK + WSPD2
          VHMF  = VHMK*FPSPKN
          VHPK  = VHPK + WSPD2
          VHPF  = VHPK*FPSPKN
      C
      C   ----------------
      C   DYNAMIC PRESSURE
      C   ----------------
      C
          QHM   = RHOD2*VHMF**2
          QP(I) = RHOD2*VHPF**2
      C
          IF(DSET.NE.0.)GOTO 77
      C
      C   ----------------------------
      C   REPORT HORIZONTAL COMPONENTS
```

```
C      ----------------------------
C
       WRITE(IOU6,1003) ZZ,VHMF,VHMK,VHPF,VHPK,QHM,QP(I)
  1003 FORMAT ( F8.2,2X,6F10.3)
    77 CONTINUE
C
   500 CONTINUE
C
       IF(DSET.NE.0.)GOTO 520
       WRITE(IOU1,73)
    73 FORMAT( )
C
       WRITE(IOU1,'(19X,A,$)')
     1  ' TYPE <RETURN> TO CONTINUE
C
       READ(IOU1,'(A1)') TEMCHAR
C
       ICD = 0
       CALL HOMCLS(ICD)
       IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
       IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
C
       WRITE(IOU6,1007) XIPOUT
  1007 FORMAT( 12X,'TWIN ROTOR FORCE PROFILE AT DISTANCE = ',
     1        F7.1,' FT',//)
       WRITE(IOU6,1008)
  1008 FORMAT( 2X,'HEIGHT',6X,'PEAK Q',6X,'FOVER',7X,'OVERM',7X,
     1             'TOT F',7X,'TOT M',/,
     2          3X,'(FT)',8X,'(PSF)',7X,'(LB)',6X,'(FT-LB)',7X,
     3             '(LB)',6X,'(FT-LB)',/)
   520 CONTINUE
C
C      ------------------------------------
C      CALL SUBROUTINE TO CALCULATE THE
C      FORCES AND MOMENTS ON A HUMAN BEING
C      ------------------------------------
C
       CALL MOMENT(NPTS,HUMTYP,TOTF,TOTM)
C
       IF(DSET.EQ.0.)GOTO 545
C
       HH    = XIP*RADIUS
       HHOUT = HH + DXO
C
       WRITE(IOU6,1014) HHOUT,TOTF,TOTM
  1014 FORMAT( 10X,F8.2,2F10.3)
C
       IF(IGRAPH.EQ.1)THEN
C
         WRITE(IOU8,90) HHOUT,TOTF,TOTM
    90   FORMAT( 1X,F7.2,1X,F7.2,1X,F8.2)
C
       ENDIF
C
   545 CONTINUE
C
       XIP = XIP + DELH
C
   565 CONTINUE
C
C      ---------------------------
C      CLOSE AN OPEN GRAPHICS FILE
```

```
C      ----------------------------
C
       IF(IGRAPH.EQ.1)THEN
C
         CLOSE(IOU8,STATUS='KEEP')
C
       ENDIF
C
       CALL INKEY
C
       GOTO 999
C
C      -----------------------------------------------
C      THE ERROR LOGIC ALLOWS FOR THE HANDLING OF FILE
C      OPEN ERRORS BY RETURNING THE USER TO A MENU
C      -----------------------------------------------
C
 2000  CONTINUE
C
       CALL HOMCLS(0)
       WRITE(IOU1,2001)
 2001  FORMAT( ////,8X,
      1        ' *** ERROR ***  PLEASE CHOOSE A NEW OUTPUT FILENAME',
      2 ///,8X,'            TYPE <RETURN> TO CONTINUE  ',$)
       READ(IOU1,'(A1)') TEMCHAR
       KEY = 'P'
C
  999  CONTINUE
C
       RETURN
       END
C
```

```
      C
      C
            SUBROUTINE HOMCLS(CODE)
      C
      C     ************************************************************
      C     SUBROUTINE HOMCLS
      C
      C     THIS SUBROUTINE HOMES THE CURSOR AND CLEARS THE TERMINAL
      C     SCREEN (CODE=0) OR HOMES THE CURSOR ONLY (CODE=1)
      C     ************************************************************
      C
            COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
      C
            INTEGER*4 CODE
      C
            CHARACTER*4 ED
            CHARACTER*1 EED(4)
            EQUIVALENCE (ED,EED(1))
      C
            CHARACTER*3 EE
            CHARACTER*1 EEE(3)
            EQUIVALENCE (EE,EEE(1))
      C
      C     ************************************************************
      C
            IF(CODE.EQ.1)GOTO 20
      C
      C     -----------------------------------
      C     HOME CURSOR AND CLEAR SCREEN
      C     ANSI CONTROL SEQUENCE: ED = ESC[2J
      C     -----------------------------------
      C
            EED(1) = CHAR(27)
            EED(2) = CHAR(91)
            EED(3) = CHAR(50)
            EED(4) = CHAR(74)
      C
            WRITE(IOU1,*) ED
      C
         20 CONTINUE
      C
      C     ----------------------------------
      C     HOME CURSOR ONLY
      C     ANSI CONTROL SEQUENCE: EE = ESC[H
      C     ----------------------------------
      C
            EEE(1) = CHAR(27)
            EEE(2) = CHAR(91)
            EEE(3) = CHAR(72)
      C
            WRITE(IOU1,*) EE
      C
            RETURN
            END
      C
```

```
C
C
      SUBROUTINE HSVTX(XT,YT,ZT,VX,VY,VZ,GAMMA,RADIUS)
C
C
******************************************************************
C     SUBROUTINE HSVTX
C
C     THIS SUBROUTINE DIRECTS THE CALCULATION OF THE INDUCED VELOCITY
C     FIELD DUE TO A HORSESHOE VORTEX SYSTEM OF UNIT STRENGTH.  POINT
:
C     (LEFT = L1, RIGHT = R1) DEFINE THE EXTENT OF THE BOUND PORTION
OF
C     THE HORSESHOE.  THE TRAILERS START AT POINT 1 AND EXTEND
THROUGH
C     POINT 2, AND THEN ON TO POINT 3.  THIS ALLOWS TWO ELEMENTS FOR
C     EACH TRAILER SO THAT IT CAN 'BEND' TO ACCOUNT FOR GROUND
CONTACT.
C
******************************************************************
C
      COMMON /CHSVTX/ XL1,YL1,ZL1,XL2,YL2,ZL2,XL3,YL3,ZL3,
     1                XR1,YR1,ZR1,XR2,YR2,ZR2,XR3,YR3,ZR3
      COMMON /CVLINE/ IFI,XA,YA,ZA,XB,YB,ZB,XC,YC,ZC,Q1,Q2,Q3
C
C
******************************************************************
C
C     ----------------------------------------------
C     AT SPECIFIED (X,Y,Z) TARGET POINT IN VICINITY
C     OF ROTOR, CALCULATE THE VECTOR VELOCITY
C     ----------------------------------------------
C
      VX = 0.0
      VY = 0.0
      VZ = 0.0
C
      XC = XT
      YC = YT
      ZC = ZT
C
C     ----------------------------------------------
C     LEFT TRAILER CONTRIBUTION, POINT 1 TO POINT 2
C     ----------------------------------------------
C
      IFI = 0
      XA = XL1
      YA = YL1
      ZA = ZL1
      XB = XL2
      YB = YL2
      ZB = ZL2
C
      CALL VLINE
C
      VX = VX - Q1
      VY = VY - Q2
      VZ = VZ - Q3
C
C     ------------------
C     LEFT TRAILER IMAGE
C     ------------------
C
```

```
      ZA = -ZA
      ZB = -ZB
C
      CALL VLINE
C
      VX = VX + Q1
      VY = VY + Q2
      VZ = VZ + Q3
C
C     ---------------------------------------------
C     LEFT TRAILER CONTRIBUTION, POINT 2 TO POINT 3
C     ---------------------------------------------
C
      IFI = 1
      XA = XL2
      YA = YL2
      ZA = ZL2
      XB = XL3
      YB = YL3
      ZB = ZL3
C
      CALL VLINE
C
      VX = VX - Q1
      VY = VY - Q2
      VZ = VZ - Q3
C
C     ------------------
C     LEFT TRAILER IMAGE
C     ------------------
C
      ZA = -ZA
      ZB = -ZB
C
      CALL VLINE
C
      VX = VX + Q1
      VY = VY + Q2
      VZ = VZ + Q3
C
C     -----------------------------
C     SPANWISE VORTEX CONTRIBUTION
C     -----------------------------
C
      IFI = 0
      XA = XL1
      YA = YL1
      ZA = ZL1
      XB = XR1
      YB = YR1
      ZB = ZR1
C
      CALL VLINE
C
      VX = VX + Q1
      VY = VY + Q2
      VZ = VZ + Q3
C
C     ---------------------
C     SPANWISE VORTEX IMAGE
C     ---------------------
C
      ZA = -ZA
```

```
      ZB = -ZB
C
      CALL VLINE
C
      VX = VX - Q1
      VY = VY - Q2
      VZ = VZ - Q3
C
C     ------------------------------------------------
C     RIGHT TRAILER CONTRIBUTION, POINT 1 TO POINT 2
C     ------------------------------------------------
C
      IFI = 0
      XA = XR1
      YA = YR1
      ZA = ZR1
      XB = XR2
      YB = YR2
      ZB = ZR2
C
      CALL VLINE
C
      VX = VX + Q1
      VY = VY + Q2
      VZ = VZ + Q3
C
C     -------------------
C     RIGHT TRAILER IMAGE
C     -------------------
C
      ZA = -ZA
      ZB = -ZB
C
      CALL VLINE
C
      VX = VX - Q1
      VY = VY - Q2
      VZ = VZ - Q3
C
C     ------------------------------------------------
C     RIGHT TRAILER CONTRIBUTION, POINT 2 TO POINT 3
C     ------------------------------------------------
C
      IFI = 1
      XA = XR2
      YA = YR2
      ZA = ZR2
      XB = XR3
      YB = YR3
      ZB = ZR3
C
      CALL VLINE
C
      VX = VX + Q1
      VY = VY + Q2
      VZ = VZ + Q3
C
C     -------------------
C     RIGHT TRAILER IMAGE
C     -------------------
C
      ZA = -ZA
      ZB = -ZB
```

```
C
      CALL VLINE
C
      VX = VX - Q1
      VY = VY - Q2
      VZ = VZ - Q3
C
C     ---------------
C     DIMENSIONALIZE
C     ---------------
C
      GDR= GAMMA/RADIUS
      VX = VX*GDR
      VY = VY*GDR
      VZ = VZ*GDR
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE HWJVEL(H,UN,UMB,RVZ,RADIUS,WSPD,DELH,HMAX,
     *                      HUMTYP,DXO,BDLAYM)
C
C     ****************************************************
C     SUBROUTINE HWJVEL GENERATES THE VELOCITY PROFILE AND
C     THE FORCES AND OVERTURNING MOMENTS FOR A HUMAN BEING
C     AT A GIVEN RADIUS
C     ****************************************************
C
      CHARACTER*1 ICONT(5)
      CHARACTER*1 TEMCHAR
      CHARACTER*1 KEY,KKEY,HUMTYP
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /PERSON/ QP(12),DSET
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ****************************************************
C
      ICD = 0
      CALL HOMCLS(ICD)
C
C     -----------------------------------------------------
C     INPUT FOR DELH AND HMAX COMES FROM INPUTV STATUS MENU
C     -----------------------------------------------------
C
      DSET = DELH
C
      IF(DSET.EQ.0.) DELH = HMAX
C
      DELH  = DELH/RADIUS
      HMAX  = HMAX/RADIUS
      NHPTS = IFIX((HMAX - RVZ)/DELH) + 1
C
      IF(DSET.EQ.0.)GOTO 50
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 10X,A50,/,10X,A50,//)
C
      WRITE(IOU6,1001)
 1001 FORMAT( 12X,' SUMMARY OF OVERTURNING FORCES AND MOMENTS',//,
     1         19X,'RADIUS',6X,'TOTF',6X,'TOTM',/,
     2         20X,'(FT)',7X,'(LB)',5X,'(FT-LB)',/)
   50 CONTINUE
C
C     ----------------------------------------------
C     WRITE OUT GRAPHICS FILE IF SWITCH IS SET BY USER
C     ----------------------------------------------
C
      IF(IGRAPH.EQ.1)THEN
C
C     ----------------------------------------
C     OPEN GRAPHICS FILE AND WRITE FILE HEADER
C     ----------------------------------------
C
```

```
      OPEN(IOU8,FILE=PTSFIL(3),STATUS='NEW',ERR=2000)
C
      WRITE(IOU8,83) COMM(1),COMM(2)
   83 FORMAT( 10X,A50,/,10X,A50,//)
C
      WRITE(IOU8,80)
   80 FORMAT( 1X,'TITLE="SINGLE ROTOR DFRC DATA"')
C
      WRITE(IOU8,81)
   81 FORMAT( 1X,'VARIABLES = DFRC,TOTF,TOTM')
C
      WRITE(IOU8,88)
   88 FORMAT( 1X,'ZONE T = "GW = xxxxx LB, WAGL = xx FT",',
     *            ' I=x, F=POINT')
C
      ENDIF
C
C     ---------------------------------------------------
C     BEGIN LOOP INCREMENTING THE RADIAL POINTS AT WHICH
C     THE OVERTURNING MOMENT CALCULATIONS ARE MADE
C     ---------------------------------------------------
C
      DO 565 K = 1,NHPTS
C
C     --------------------------------------------------
C     'PROPRM' PROVIDES THE VELOCITY PROFILE PARAMETERS
C     OF A RADIAL WALL JET (WITHOUT INTERACTION PLANE)
C     --------------------------------------------------
C
      CALL PROPRM(H,UMB,RVZ)
C
      ZETAM = ZM/ZB
      ZETAH = ZH/ZB
C
C     ---------------------------------------------------------
C     CALCULATION OF THE NON-DIMENSIONALIZED MINIMUM ALLOWED
C     BOUNDARY LAYER THICKNESS SO THAT THE BOUNDARY LAYER CAN
C     BE ADJUSTED IF THE ZM POSITION IS PHYSICALLY TOO LOW
C     (BDLAYM, IN FEET, COMES FROM A MENU INPUT PARAMETER)
C     ---------------------------------------------------------
C
      ZETA1 = BDLAYM/ZB
C
C     ------------------------------
C     BOUNDARY LAYER REGION EXPONENT
C     'AN' IS ACTUALLY '= 1.0/7.0'
C     ------------------------------
C
      AN = 0.142857142
C
C     ---------------------------------------------------------------
C     SHEAR LAYER REGION EXPONENT, TO MEET EDGE CONDITIONS
C     (FROM FIGURE 7, USAAVLABS TECHNICAL REPORT 68-52, JULY 1968)
C     ---------------------------------------------------------------
C
      ALPW = ALOG(1.0 - 1.0/SQRT(2.0))/ALOG((ZH - ZM)/(ZB - ZM))
C
      VN  = UN
      VMN = UM
C
C     ---------------------------------------------------------------
C     PRINT DETAILED REPORT IF DSET = 0.0 INSTEAD OF SIMPLE REPORT
C     ---------------------------------------------------------------
```

```
C
      IF(DSET.NE.0.)GOTO 78
C
      RRVZ    = RVZ*RADIUS
      RVZOUT = RRVZ + DXO
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
C
      WRITE(IOU6,1000) RVZOUT
 1000 FORMAT( 10X,'SINGLE ROTOR VELOCITY PROFILE AT RADIUS = ',
     1       F7.1,' FT',//)
      WRITE(IOU6,1005)
 1005 FORMAT( 2X,'HEIGHT',5X,'MEAN VELOCITY',7X,'PEAK VELOCITY',6X,
     1       'MEAN Q',4X,'PEAK Q',/,
     2       3X,'(FT)',5X,'(FPS)',6X,'(KN)',5X,'(FPS)',6X,'(KN)',5X,
     3       '(PSF)',5X,'(PSF)',/)
   78 CONTINUE
C
C     ---------------------------------------
C     SET UP ABILITY TO CALCULATE AT 0.5 FT.
C     INCREMENTS UP THE VELOCITY PROFILE
C     ---------------------------------------
C
      DELZ = 0.5/RADIUS
      NPTS = 12
C
      DO 500 I = 1,NPTS
C
      Z    = DELZ*(I - 1) + (0.25/RADIUS)
      ZETA = Z/ZB
C
      IF(ZETA.LT.ZETAM.OR.ZETA.LT.ZETA1)THEN
C
C             ---------------------------------------------------
C             Z IS WITHIN BOUNDARY LAYER
C
C             NOTE THAT THE BOUNDARY LAYER CALCULATIONS NOW USE
C             THE MINIMUM THICKNESS PARAMETER AND THE PEAK TO
C             MEAN VELOCITY PARAMETER IS THE MAXIMUM VELOCITY
C       HEIGHT RATIO (AT ZM).  ADDED MAY 1992 FOR V2.1.
C             ---------------------------------------------------
C
              VZM = 0.0
C
              IF(ZETAM.GT.0.0)THEN
C
                VZM = (ZETA/ZETAM)**AN
C
                IF(ZETA1.GT.ZETAM)THEN
C
            VZM1 = (1.0 - ((ZETA1 - ZETAM)/(1.0 - ZETAM))**ALPW)**2
            VZM  = VZM1*(ZETA/ZETA1)**AN
C
                ENDIF
C
                VMTOPK = 1.04653 + 0.373894*RVZ - 0.0422525*RVZ*RVZ
C
                IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
              ENDIF
C
```

```
                GOTO 400
C
        ENDIF
C
C       ----------------------------------------------------
C       Z IS WITHIN SHEAR LAYER
C
C       THE PEAK TO MEAN VELOCITY RATIO EQUATIONS ARE
C       SUBSTANTIALLY IMPROVED OVER THOSE USED PRIOR TO
C       MAY 1992.  EQUATIONS ARE NOW USED FOR BOTH THE
C       MAXIMUM VELOCITY HEIGHT (ZM) AND THE 1/2 VELOCITY
C       HEIGHT (ZH).  VALUES BETWEEN ARE INTERPOLATED AND
C       VALUES ABOVE ZH USE THE ZH RATIO*(ZETA/ZETAH).
C       THESE 2nd ORDER EQUATION SUBSTANTIALLY IMPROVED
C       CORRELATION WITH MODEL AND FLIGHT TEST DATA
C       DURING THE MAY 1992 EFFORT FOR V2.1.
C       ----------------------------------------------------
C
        VZM = 0.0
C
        IF(Z.LE.ZB)THEN
C
                VZM = (1.0 - ((ZETA - ZETAM)/(1.0 - ZETAM))**ALPW)**2
C
                IF(ZETA.GE.ZETAH)THEN
C
                  VMTOPK = (1.48086 + 0.569177*RVZ - 0.0692514*RVZ*RVZ)
     1                           *(ZETA/ZETAH)
C
                  IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
                ELSE
C
                  VMPKMX = 1.04653 + 0.373894*RVZ - 0.0422525*RVZ*RVZ
C
                  VMPK12 = 1.48086 + 0.569177*RVZ - 0.0692514*RVZ*RVZ
C
                  FRAC          = (ZETA - ZETAM)/(ZETAH - ZETAM)
C
                  IF(ZETA1.GT.ZETAM)THEN
C
              FRAC   = (ZETA - ZETA1)/(ZETAH - ZETA1)
C
                  ENDIF
C
                  VMTOPK = FRAC*VMPK12 + (1.0 - FRAC)*VMPKMX
C
                  IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
                ENDIF
C
        ENDIF
C
    400 CONTINUE
C
        VZN = VZM*VMN
C
C       -------------------
C       DIMENSIONAL HEIGHT
C       -------------------
C
        ZZ  = Z*RADIUS
C
```

```
C     ---------------
C     MEAN VELOCITIES
C     ---------------
C
      VMF = VZN*VN
      VMK = VMF/FPSPKN
C
C     ---------------
C     PEAK VELOCITIES
C     ---------------
C
      VPF = VMF*VMTOPK
      VPK = VPF/FPSPKN
C
C     ----------------------------------------------------------
C     THE EFFECT OF WIND IS TO ADD (DOWNWIND SIDE) OR SUBTRACT
C     (UPWIND SIDE) 'XWK' TIMES THE AMBIENT WIND VELOCITY TO
C     THE HORIZONTAL PROFILE VELOCITY (EMPIRICAL, CH-53E BASED)
C     ----------------------------------------------------------
C
      XKW = (-0.5*H) + 2.5
C
      IF(XKW.LT.1.0) XKW = 1.0
C
      WSPD2 = WSPD*XKW
      VMK   = VMK + WSPD2
      VMF   = VMK*FPSPKN
      VPK   = VPK + WSPD2
      VPF   = VPK*FPSPKN
C
C     ----------------
C     DYNAMIC PRESSURE
C     ----------------
C
      QM    = RHOD2*VMF**2
      QP(I) = RHOD2*VPF**2
C
      IF(DSET.NE.0.)GOTO 77
C
      WRITE(IOU6,1002) ZZ,VMF,VMK,VPF,VPK,QM,QP(I)
 1002 FORMAT( F8.2,6F10.3)
   77 CONTINUE
C
  500 CONTINUE
C
      IF(DSET.NE.0.)GOTO 520
C
      WRITE(IOU1,73)
   73 FORMAT( )
C
      WRITE(IOU1,'(15X,A,$)')
     1 ' TYPE <RETURN> TO CONTINUE '
C
      READ(IOU1,'(A1)') TEMCHAR
C
      ICD = 0
      CALL HOMCLS(ICD)
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
C
      WRITE(IOU6,1007) RVZOUT
 1007 FORMAT( 12X,'SINGLE ROTOR FORCE PROFILE AT RADIUS = ',
```

```
     1        F7.1,' FT',//)
C
      WRITE(IOU6,1008)
 1008 FORMAT( 2X,'HEIGHT',6X,'PEAK Q',6X,'FOVER',7X,'OVERM',7X,
     1        'TOT F',7X,'TOT M',/,
     2        3X,'(FT)',8X,'(PSF)',7X,'(LB)',6X,'(FT-LB)',7X,
     3        '(LB)',6X,'(FT-LB)',/)
C
  520 CONTINUE
C
C     ----------------------------------
C     CALL SUBROUTINE TO CALCULATE THE
C     FORCES AND MOMENTS ON A HUMAN BEING
C     ----------------------------------
C
      CALL MOMENT(NPTS,HUMTYP,TOTF,TOTM)
C
      IF(DSET.EQ.0.)GOTO 545
C
      HH    = RVZ*RADIUS
      HHOUT = HH + DXO
C
      WRITE(IOU6,1014) HHOUT,TOTF,TOTM
 1014 FORMAT( 18X,F8.2,2F10.3)
C
      IF(IGRAPH.EQ.1)THEN
C
        WRITE(IOU8,90) HHOUT,TOTF,TOTM
   90   FORMAT( 1X,F7.2,1X,F7.2,1X,F8.2)
C
      ENDIF
C
  545 CONTINUE
C
      RVZ = RVZ + DELH
C
  565 CONTINUE
C
C     -------------------------
C     CLOSE AN OPEN GRAPHICS FILE
C     -------------------------
C
      IF(IGRAPH.EQ.1)THEN
C
        CLOSE(IOU8,STATUS='KEEP')
C
      ENDIF
C
      CALL INKEY
C
      GOTO 999
C
C     ---------------------------------------------
C     THE ERROR LOGIC ALLOWS FOR THE HANDLING OF FILE
C     OPEN ERRORS BY RETURNING THE USER TO A MENU
C     ---------------------------------------------
C
 2000 CONTINUE
C
      CALL HOMCLS(0)
      WRITE(IOU1,2001)
 2001 FORMAT( ////,8X,
     1        ' *** ERROR ***  PLEASE CHOOSE A NEW OUTPUT FILENAME',
```

```
     2 ///,8X,'                    TYPE <RETURN> TO CONTINUE   ',$)
      READ(IOU1,'(A1)') TEMCHAR
      KEY = 'P'
C
  999 CONTINUE
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE INKEY
C
C     ******************************************************
C     SUBROUTINE INKEY
C     ******************************************************
C
      PARAMETER(NUM = 8)
C
      CHARACTER*1 KEY,KKEY
      CHARACTER*1 OKLIST(NUM)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ******************************************************
C
      DATA OKLIST /'C','c','P','p','N','n','X','x'/
C
C     ------------------------------------------------
C     INQUIRE, OBTAIN, AND CHECK FOR VALID MENU OPTION
C     ------------------------------------------------
C
   10 CONTINUE
C
      WRITE(IOU1,20)
   20 FORMAT( //,7X,' TYPE <C>ONTINUE, NEXT <P>OINT, <N>EW CASE.'
     1          ,' E<X>IT --> ',$)
      READ(IOU1,'(A1)') KEY
C
      IF(LEGAL(KEY,IOU1,OKLIST,NUM).EQ.1)GOTO 10
C
C     ------------------------------------------
C     CORRECT LOWER CASE LETTERS TO UPPER CASE
C     TO USE AS VALID FLAGS IN PARENT SUBROUTINE
C     ------------------------------------------
C
      IF(KEY.EQ.'c') KEY = 'C'
      IF(KEY.EQ.'p') KEY = 'P'
      IF(KEY.EQ.'n') KEY = 'N'
      IF(KEY.EQ.'x') KEY = 'X'
C
C     ----------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ----------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE INPUT
C
C     **********************************************************
C     SUBROUTINE INPUT
C
C     THIS SUBROUTINE PRESENTS THE INPUT STATUS MENU
C     AND MANIPULUTES THE DATA FOR PROGRAM USE
C     **********************************************************
C
      PARAMETER(NUM1 = 19)
      PARAMETER(NUM2 =  9)
      PARAMETER(NUM3 =  4)
      PARAMETER(NUM4 =  4)
C
      CHARACTER*1 CHDOL
      CHARACTER*1 CENTRY
      CHARACTER*1 OKLST1(NUM1)
      CHARACTER*1 OKLST2(NUM2)
      CHARACTER*1 OKLST3(NUM3)
      CHARACTER*1 OKLST4(NUM4)
      CHARACTER*1 ICONT(5)
C
      CHARACTER*12 PTSFIL(4)
C
      CHARACTER*50 COMM(2),LENTRY
      CHARACTER*50 PROMPT
C
      DIMENSION CONT(9),CONTV(7),CONTX(8)
C
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /INPUTD/ CONT,CONTV,CONTX,YBDLAY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     **********************************************************
C
C     -----------------------------------------
C     SET DATA TO CHECK FOR ILLEGAL DATA INPUT
C     -----------------------------------------
C
      DATA OKLST1 /' ','A','a','B','b','C','c','D','d',
     1             'E','e','F','f','G','g','H','h','I','i'/
      DATA OKLST2 /' ','A','a','B','b','C','c','D','d'/
      DATA OKLST3 /'V','v','H','h'/
      DATA OKLST4 /'Y','y','N','n'/
C
   10 CONTINUE
C
C     -----------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     -----------------------------
C
      CALL HOMCLS(0)
      CALL LOCATE(2,1)
C
C     ----------------------------------
C     WRITE FIRST ENGINEERING DATA MENU
C     ----------------------------------
C
      IROTOR = IFIX(CONT(1))
C
      WRITE(IOU1,'(24X,A/)') ' ROTWASH USER INPUT DATA MENU'
```

```
      WRITE(IOU1,'(T7,A,T25,A,T51,A,T61,A/)') ' CODE',' PARAMETER',
     1      ' VALUE',' UNITS'
      WRITE(IOU1,'(8X,A,T50,I5,8X,A)')
     1      ' A        NUMBER OF ROTORS (1 OR 2)  ',IROTOR,'-ND-'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' B        HUB TO HUB ROTOR SEPARATION',CONT(2),'FT'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' C        ROTOR RADIUS               ',CONT(3),'FT'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' D        GROSS WEIGHT               ',CONT(4),'LB'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' E        FUSELAGE DOWNLOAD FACTOR   ',CONT(5),'PCT'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' F        ROTOR HEIGHT ABOVE GROUND  ',CONT(6),'FT'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A)')
     1      ' G        SHAFT TILT ANGLE (<20 DEG) ',CONT(7),'DEG'
      WRITE(IOU1,'(8X,A,T50,F8.4,6X,A)')
     1      ' H        AIR DENSITY RATIO          ',CONT(8),'ND'
      WRITE(IOU1,'(8X,A,T50,F8.1,6X,A//)')
     1      ' I        AMBIENT WIND (-10 TO 10 KT)',CONT(9),'KT'
C
C     ---------------------------------------------------
C     PROMPT FOR, OBTAIN, AND CHECK FOR LEGAL INPUT DATA
C     ---------------------------------------------------
C
   20 WRITE(IOU1,'(8X,A,$)')
     1' ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==> '
C
      READ(IOU1,'(A1)') CHDOL
C
      IF(LEGAL(CHDOL,IOU1,OKLST1,NUM1).EQ.1)GOTO 20
C
      IF(CHDOL.EQ.' ')GOTO 30
C
      IF(CHDOL.EQ.'A'.OR.CHDOL.EQ.'a')THEN
C
         PROMPT = 'ROTORS = '
         CALL IREAD(IOU1,PROMPT,IROTOR)
C
         IF(IROTOR.LT.1) IROTOR = 1
         IF(IROTOR.GT.2) IROTOR = 2
         CONT(1) = FLOAT(IROTOR)
C
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'B'.OR.CHDOL.EQ.'b')THEN
C
         PROMPT = 'ROTOR SEPARATION = '
         CALL FREAD(IOU1,PROMPT,CONT(2),1.0)
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'C'.OR.CHDOL.EQ.'c')THEN
C
         PROMPT = 'ROTOR RADIUS = '
         CALL FREAD(IOU1,PROMPT,CONT(3),1.0)
         GOTO 10
C
      ENDIF
C
```

```
      IF(CHDOL.EQ.'D'.OR.CHDOL.EQ.'d')THEN
C
         PROMPT = 'GROSS WEIGHT = '
         CALL FREAD(IOU1,PROMPT,CONT(4),1.0)
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'E'.OR.CHDOL.EQ.'e')THEN
C
         PROMPT = 'DOWNLOAD FACTOR = '
         CALL FREAD(IOU1,PROMPT,CONT(5),1.0)
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'F'.OR.CHDOL.EQ.'f')THEN
C
         PROMPT = 'HEIGHT ABOVE GROUND = '
         CALL FREAD(IOU1,PROMPT,CONT(6),1.0)
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'G'.OR.CHDOL.EQ.'g')THEN
C
         PROMPT = 'SHAFT TILT = '
         CALL FREAD(IOU1,PROMPT,CONT(7),1.0)
C
         IF(CONT(7).LT. 0.0) CONT(7) =  0.0
         IF(CONT(7).GT.20.0) CONT(7) = 20.0
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'H'.OR.CHDOL.EQ.'h')THEN
C
         PROMPT = 'DENSITY RATIO = '
         CALL FREAD(IOU1,PROMPT,CONT(8),1.0)
         GOTO 10
C
      ENDIF
C
      IF(CHDOL.EQ.'I'.OR.CHDOL.EQ.'i')THEN
C
         PROMPT = 'WIND VELOCITY = '
         CALL FREAD(IOU1,PROMPT,CONT(9),1.0)
C
         IF(CONT(9).LT.-10.0) CONT(9) = -10.0
         IF(CONT(9).GT. 10.0) CONT(9) =  10.0
         GOTO 10
C
      ENDIF
C
      GOTO 10
C
   30 CONTINUE
C
C     ------------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ------------------------------
C
      CALL HOMCLS(0)
```

```
      CALL LOCATE(2,1)
C
C     ---------------------------------
C     WRITE SECOND ENGINEERING DATA MENU
C     ---------------------------------
C
      WRITE(IOU1,40)
   40 FORMAT( ' ',18X,' ROTWASH PROGRAM LOGIC/COMMENT MENU',//,
     1       10X,'CODE                PARAMETER                     VALUE'/)
C
      WRITE(IOU1,50) ICONT(1),ICONT(2),COMM(1),COMM(2)
   50 FORMAT( 12X,'A       ANALYSIS TYPE,     <V> OR <H>',5X,A4,/,
     1          12X,'B       GRAPHICS FILE,     <Y> OR <N>',5X,A4,///,
     2          15X,'USER INPUT COMMENTS (FOR "PRN" AND "PLT" OUTPUT)',
     3    //,17X,'<---                   50 SPACES                    --->',
     4       /,12X,'C',4X,A50,/,
     5          12X,'D',4X,A50,//)
C
C     -----------------------------------------------
C     PROMPT FOR, OBTAIN, AND CHECK FOR LEGAL INPUT DATA
C     -----------------------------------------------
C
   60 WRITE(IOU1,'(8X,A,$)')
     1' ENTER CODE FOR DATA INPUT OR <RETURN> TO CONTINUE ==> '
C
      READ(IOU1,'(A1)') CHDOL
C
      IF(LEGAL(CHDOL,IOU1,OKLST2,NUM2).EQ.1)GOTO 60
C
      IF(CHDOL.EQ.' ')GOTO 70
C
C     ----------------------------------------
C     CHOOSE VELOCITY OR HAZARD ANALYSIS OPTION
C     ----------------------------------------
C
      IF(CHDOL.EQ.'A'.OR.CHDOL.EQ.'a')THEN
C
   80    CONTINUE
C
         WRITE(IOU1,'(/,35X,A,1X,A2/)') ' ANALYSIS TYPE = ',ICONT(1)
         WRITE(IOU1,'(40X,A,$)') ' ENTER NEW VALUE   ==> '
         READ(IOU1,'(A1)') CENTRY
C
         IF(LEGAL(CENTRY,IOU1,OKLST3,NUM3).EQ.1)GOTO 80
C
         ICONT(1) = CENTRY
         IF(ICONT(1).EQ.'v') ICONT(1) = 'V'
         IF(ICONT(1).EQ.'h') ICONT(1) = 'H'
         GOTO 30
C
      ENDIF
C
C     --------------------------------------
C     CHOOSE OUTPUT TO A GRAPHICS FILE OR NOT
C     --------------------------------------
C
      IF(CHDOL.EQ.'B'.OR.CHDOL.EQ.'b')THEN
C
   90    CONTINUE
C
         WRITE(IOU1,'(/,35X,A,1X,A2/)') ' GRAPHICS FLAG = ',ICONT(2)
         WRITE(IOU1,'(40X,A,$)') ' ENTER NEW VALUE   ==> '
         READ(IOU1,'(A1)') CENTRY
```

```
C
            IF(LEGAL(CENTRY,IOU1,OKLST4,NUM4).EQ.1)GOTO 90
C
            ICONT(2) = CENTRY
            IF(ICONT(2).EQ.'y') ICONT(2) = 'Y'
            IF(ICONT(2).EQ.'n') ICONT(2) = 'N'
            IF(ICONT(2).EQ.'Y') IGRAPH = 1
            IF(ICONT(2).EQ.'N') IGRAPH = 0
            GOTO 30
C
         ENDIF
C
C        -----------------------------------------
C        CHOOSE COMMENT STRINGS FOR OUTPUT DATA
C        -----------------------------------------
C
         IF(CHDOL.EQ.'C'.OR.CHDOL.EQ.'c')THEN
C
            WRITE(IOU1,'(/,5X,A,A50/)') ' COMMENT STRING = ',COMM(1)
            WRITE(IOU1,'(5X,A,$)') ' ENTER STRING --> '
            READ(IOU1,'(A50)') LENTRY
C
            COMM(1) = LENTRY
            GOTO 30
C
         ENDIF
C
         IF(CHDOL.EQ.'D'.OR.CHDOL.EQ.'d')THEN
C
            WRITE(IOU1,'(/,5X,A,A50/)') ' COMMENT STRING = ',COMM(2)
            WRITE(IOU1,'(5X,A,$)') ' ENTER STRING --> '
            READ(IOU1,'(A50)') LENTRY
C
            COMM(2) = LENTRY
            GOTO 30
C
         ENDIF
C
         GOTO 30
C
      70 CONTINUE
C
         RETURN
         END
C
```

```
C
C
      SUBROUTINE INPUTV(FLOW)
C
C     *************************************************************
C     SUBROUTINE INPUTV
C
C     THIS SUBROUTINE PRESENTS THE INPUT STATUS MENU AND MANIPULATES
C     DATA FOR FOR THE WALJET AND IPLANE PROGRAM OPTIONS
C     *************************************************************
C
      PARAMETER(NUM = 11)
C
      CHARACTER*1 OKLIST(NUM)
      CHARACTER*1 CHDOL,FLOW
      CHARACTER*1 ICONT(5)
      CHARACTER*12 TMPFIL
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
      CHARACTER*50 PROMPT
C
      DIMENSION CONT(9),CONTV(7),CONTX(8)
C
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /INPUTD/ CONT,CONTV,CONTX,YBDLAY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     *************************************************************
C
      DATA OKLIST /' ','A','a','B','b','C','c','D','d','E','e'/
C
C     ----------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ----------------------------
C
      ICD = 0
C
   20 CONTINUE
C
      CALL HOMCLS(ICD)
      CALL LOCATE(1,1)
C
      WRITE(IOU1,12)
   12 FORMAT( 22X,' VELOCITY PROFILE STATUS MENU',///,
     1       10X,'CODE          PARAMETER                  VALUE',
     2        3X,'UNITS',/)
C
C     ------------------------------------------------
C     PRINT OUT MENU VARIABLES AS BASED ON THE WALL JET
C     OPTION OR INTERACTION PLANE OPTION SWITCH SETTING
C     ------------------------------------------------
C
      IF(FLOW.EQ.'W')THEN
C
         WRITE(IOU1,14)(CONTV(I),I=1,3),YBDLAY,PTSFIL(1)
C
      ELSE
C
         WRITE(IOU1,14)(CON[illegible](I),I=1,3),YBDLAY,PTSFIL(2)
C
      ENDIF
C
   14 FORMAT( 12X,'A      PROFILE STATION POSITION ',5X,F7.2,
```

```
     1   4X,'FT',/,
     2  12X,'B      VERTICAL INCREMENT        ',4X,F7.2,4X,'FT',/,
     3  12X,'C      MAXIMUM PROFILE HEIGHT    ',4X,F7.2,4X,'FT',//,
     4  12X,'D      MINIMUM BOUNDARY LAYER
HEIGHT',1X,F7.2,4X,'FT',//,
     5  12X,'E      DATA OUTPUT FILENAME     ',7X,A12,//)
C
C     ---------------------------------------------------
C     PROMPT FOR, OBTAIN, AND CHECK FOR LEGAL INPUT DATA
C     ---------------------------------------------------
C
   10 CONTINUE
C
      WRITE(IOU1,'(8X,A,$)')
     1 ' ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==> '
C
      READ(IOU1,'(A1)') CHDOL
C
      IF(LEGAL(CHDOL,IOU1,OKLIST,NUM).EQ.1)GOTO 10
C
      IF(CHDOL.EQ.' ')GOTO 30
C
      IF(CHDOL.EQ.'A'.OR.CHDOL.EQ.'a')THEN
C
         PROMPT = 'PROFILE STATION POSITION = '
         CALL FREAD(IOU1,PROMPT,CONTV(1),1.0)
C
         IF(CONTV(1).LT.0.0) CONTV(1) = 0.0
         GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'B'.OR.CHDOL.EQ.'b')THEN
C
         PROMPT = 'VERTICAL INCREMENT = '
         CALL FREAD(IOU1,PROMPT,CONTV(2),1.0)
C
         IF(CONTV(2).LT.0.0) CONTV(2) = 0.0
         GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'C'.OR.CHDOL.EQ.'c')THEN
C
         PROMPT = 'MAXIMUM PROFILE HEIGHT = '
         CALL FREAD(IOU1,PROMPT,CONTV(3),1.0)
C
         IF(CONTV(3).LT.0.0) CONTV(3) = 0.0
         GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'D'.OR.CHDOL.EQ.'d')THEN
C
         PROMPT = 'MINIMUM BOUNDARY LAYER HEIGHT = '
         CALL FREAD(IOU1,PROMPT,YBDLAY,1.0)
C
         IF(YBDLAY.LT.0.0) YBDLAY = 0.0
         GOTO 20
C
      ENDIF
C
C     -------------------------
```

```
C      CHOOSE GRAPHICS FILENAME
C      ------------------------
C
       IF(CHDOL.EQ.'E'.OR.CHDOL.EQ.'e')THEN
C
         IF(FLOW.EQ.'W')THEN
           WRITE(IOU1,'(/,25X,A,1X,A12/)')
     1         ' FILENAME = ',PTSFIL(1)
         ELSE
           WRITE(IOU1,'(/,25X,A,1X,A12/)')
     1         ' FILENAME = ',PTSFIL(2)
         ENDIF
C
         WRITE(IOU1,'(20X,A,$)')
     1 ' ENTER NEW FILENAME (xxxxxxxx.xxx) ==> '
C
         READ(IOU1,'(A12)') TMPFIL
C
         IF(FLOW.EQ.'W') PTSFIL(1) = TMPFIL
         IF(FLOW.EQ.'I') PTSFIL(2) = TMPFIL
         GOTO 20
C
       ENDIF
C
       GOTO 20
C
    30 CONTINUE
C
       ICD = 0
       CALL HOMCLS(ICD)
C
       RETURN
       END
C
```

```
C
C
      SUBROUTINE INPUTX
C
C     ******************************************************
C     SUBROUTINE INPUTX PRESENTS THE INPUT STATUS MENU AND
C     MANIPULATES DATA FOR PROGRAM USE WITH THE GROUND AND
C     DISC VORTEX OPTIONS
C     ******************************************************
C
      PARAMETER(NUM = 15)
C
      CHARACTER*1 OKLIST(NUM)
      CHARACTER*1 CHDOL
      CHARACTER*1 ICONT(5)
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
      CHARACTER*50 PROMPT
C
      DIMENSION CONT(9),CONTV(7),CONTX(8)
C
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /INPUTD/ CONT,CONTV,CONTX,YBDLAY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ******************************************************
C
      DATA OKLIST /' ','A','a','B','b','C','c','D','d',
     1              'E','e','F','f','G','g'/
C
C     ----------------------------
C     CLEAR SCREEN AND HOME CURSOR
C     ----------------------------
C
      ICD = 0
C
   20 CONTINUE
C
      CALL HOMCLS(ICD)
      CALL LOCATE(1,1)
C
      WRITE(IOU1,10)
   10 FORMAT( 18X,' GROUND/DISK VORTEX INPUT DATA MENU',/,
     1         15X,' (FOR SINGLE MAIN ROTOR HELICOPTERS ONLY)',///,
     1         8X,'CODE          PARAMETER                    VALUE',
     2         4X,'UNITS',/)
C
      WRITE(IOU1,11)(CONTX(I),I=1,7)
   11 FORMAT( 10X,'A      ROTOR TIP SPEED            ',5X,F8.2,
     1      4X,'FPS',/,
     2     10X,'B     NUMBER OF ROTOR BLADES    ',5X,F8.2,4X,'-ND-',/,
     3     10X,'C     TRANSLATIONAL SPEED       ',5X,F8.2,4X,'KTS',/,
     4     10X,'D     XT POSITION               ',5X,F8.2,4X,'FT',/,
     5     10X,'E     YT POSITION               ',5X,F8.2,4X,'FT',/,
     6     10X,'F     ZT CALCULATION INCREMENT  ',5X,F8.2,4X,'FT',/,
     7     10X,'G     MAXIMUM CALCULATION HEIGHT',5X,F8.2,4X,'FT',///)
C
C     ----------------------------------------------
C     INQUIRE, OBTAIN, AND CHECK FOR VALID MENU OPTION
C     ----------------------------------------------
C
   40 CONTINUE
C
```

```
      WRITE(IOU1,'(8X,A,$)')
     1 ' ENTER DATA ENTRY CODE OR <RETURN> TO CONTINUE ==> '
C
      READ(IOU1,'(A1)') CHDOL
C
      IF(LEGAL(CHDOL,IOU1,OKLIST,NUM).EQ.1)GOTO 40
C
      IF(CHDOL.EQ.' ')GOTO 30
C
      IF(CHDOL.EQ.'A'.OR.CHDOL.EQ.'a')THEN
C
        PROMPT = 'ROTOR TIP SPEED = '
        CALL FREAD(IOU1,PROMPT,CONTX(1),1.0)
C
        IF(CONTX(1).LT.0.0) CONTX(1) = 0.0
        GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'B'.OR.CHDOL.EQ.'b')THEN
C
        PROMPT = 'NUMBER OF ROTOR BLADES = '
        CALL FREAD(IOU1,PROMPT,CONTX(2),1.0)
C
        IF(CONTX(2).LT.2.0) CONTX(2) = 2.0
        GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'C'.OR.CHDOL.EQ.'c')THEN
C
        PROMPT = 'TRANSLATIONAL SPEED = '
        CALL FREAD(IOU1,PROMPT,CONTX(3),1.0)
C
        IF(CONTX(3).LT.0.0) CONTX(3) = 0.0
        GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'D'.OR.CHDOL.EQ.'d')THEN
C
        PROMPT = 'XT POSITION = '
        CALL FREAD(IOU1,PROMPT,CONTX(4),1.0)
        GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'E'.OR.CHDOL.EQ.'e')THEN
C
        PROMPT = 'YT POSITION = '
        CALL FREAD(IOU1,PROMPT,CONTX(5),1.0)
        GOTO 20
C
      ENDIF
C
      IF(CHDOL.EQ.'F'.OR.CHDOL.EQ.'f')THEN
C
        PROMPT = 'ZT CALCULATION INCREMENT = '
        CALL FREAD(IOU1,PROMPT,CONTX(6),1.0)
C
        IF(CONTX(6).LT.0.0) CONTX(6) = 0.0
        GOTO 20
C
```

```
      ENDIF
C
      IF(CHDOL.EQ.'G'.OR.CHDOL.EQ.'g')THEN
C
        PROMPT = 'MAXIMUM CALCULATION HEIGHT = '
        CALL FREAD(IOU1,PROMPT,CONTX(7),1.0)
C
        IF(CONTX(7).LT.0.0) CONTX(7) = 0.0
        GOTO 20
C
      ENDIF
C
      GOTO 20
C
   30 CONTINUE
C
      ICD = 0
      CALL HOMCLS(ICD)
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE IOFNSH
C
C     **************************************************
C     SUBROUTINE IOFNSH CLOSES FILES OPENED FOR DISK I/O
C     **************************************************
C
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     **************************************************
C
C     ----------------------------------------------
C     KEEP STANDARD I/O FILES IF ON DISK, ELSE DELETE
C     ----------------------------------------------
C
      IF(IOU5.EQ.5) CLOSE(IOU5,STATUS='KEEP')
      IF(IOU6.EQ.6) CLOSE(IOU6,STATUS='KEEP')
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE IOINIT
C
C     ***************************************************
C     SUBROUTINE IOINIT DISPLAYS THE OPENING BANNER
C     AND OPENS THE FILES FOR DISK I/O, FILENAMES
C     ARE PROMPTED FROM THE TERMINAL
C     ***************************************************
C
      CHARACTER*3 IPFILE,OPFILE
      CHARACTER*1 TEMCHAR
C
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ***************************************************
C
C     -------------------------------------------
C     ASSIGN DEFAULT VALUES TO I/O UNIT POINTERS
C     -------------------------------------------
C
      IOU1   = 0
      IOU4   = 0
      IOU5   = 0
      IOU6   = 6
      IOU7   = 0
      IOU8   = 8
      IGRAPH = 0
C
C     ---------------------------------
C     HOME CURSOR AND CLEAR THE DISPLAY
C     ---------------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
C
C     ---------------
C     DISPLAY BANNER
C     ---------------
C
      CALL LOCATE(5,1)
C
C     ------------------------------------------------
C     ORIGINAL ROTHAZ PROGRAM WAS VERSION 1.0
C     FIRST VAX MENU VERSION OF ROTHAZ WAS VERSION 1.1
C     PROGRAM ROTWASH REPLACES ROTHAZ AT VERSION 2.0
C     ------------------------------------------------
C
      WRITE(IOU1,10)
   10 FORMAT( 27X,'ROTWASH PROGRAM',//
     1 /,17X,'ROTORCRAFT DOWNWASH HAZARD ANALYSIS',/
     2 /,18X,'EMA / SYSTEMS CONTROL TECHNOLOGY',
     3 /,15X,'*** PROGRAM VERSION 2.1, APRIL 1993 ***'
     4 ///////)
C
      WRITE(IOU1,'(A,$)')
     1  '                             PRESS <RETURN>      '
      READ(IOU1,'(A1)') TEMCHAR
C
C     ---------------------------------
C     HOME CURSOR AND CLEAR THE DISPLAY
C     ---------------------------------
C
```

```
      ICD = 0
      CALL HOMCLS(ICD)
      CALL LOCATE(3,1)
C
C     -------------------------------------------
C     PROMPT FOR I/O FILES AND READ USER RESPONSE
C     -------------------------------------------
C
      WRITE(IOU1,12)
   12 FORMAT( 14X,' I/O CAN BE DIRECTED TO FILES OR DEVICES',//,
     1        19X,' VALID DEVICES ARE AS FOLLOWS:',//,
     2        22X,'  <CON>  -->  CONSOLE',/,
     2        22X,'  <PRN>  -->  PRINTER',/,
     4        22X,'  <PLT>  -->  GRAPHICS FILE',///)
C
   16 CONTINUE
C
      WRITE(IOU1,13)
   13 FORMAT( 16X,' ENTER INPUT FILE/DEV NAME  --> ',$)
   11 FORMAT(A)
      READ(IOU1,11) IPFILE
C
C     --------------------------
C     CHECK FOR DATA ENTRY ERROR
C     --------------------------
C
      IF(IPFILE.NE.'CON'.AND.IPFILE.NE.'con')THEN
         WRITE(IOU1,15)
   15    FORMAT(/,16X,' ** INPUT ERROR, PLEASE REENTER **',//)
         GOTO 16
      ENDIF
C
   17 CONTINUE
C
      WRITE(IOU1,14)
   14 FORMAT( 16X,' ENTER OUTPUT FILE/DEV NAME --> ',$)
      READ(IOU1,11) OPFILE
C
C     --------------------------
C     CHECK FOR DATA ENTRY ERROR
C     --------------------------
C
      IF(OPFILE.NE.'CON'.AND.OPFILE.NE.'con'.AND.
     1   OPFILE.NE.'PRN'.AND.OPFILE.NE.'prn'.AND.
     2   OPFILE.NE.'PLT'.AND.OPFILE.NE.'plt')THEN
         WRITE(IOU1,15)
         GOTO 17
      ENDIF
C
C     ----------------------------------------
C     REDIRECT INPUT/OUTPUT FILES IF REQUESTED
C     ----------------------------------------
C
      IF(IPFILE.EQ.'CON'.OR.IPFILE.EQ.'con')IOU5 = IOU1
      IF(OPFILE.EQ.'CON'.OR.OPFILE.EQ.'con')IOU6 = IOU1
      IF(OPFILE.EQ.'PRN'.OR.OPFILE.EQ.'prn')IOU6 = 6
C
      IF(OPFILE.EQ.'PLT'.OR.OPFILE.EQ.'plt')IGRAPH = 1
      IF(OPFILE.EQ.'PLT'.OR.OPFILE.EQ.'plt')IOU6 = IOU1
      IF(OPFILE.EQ.'PLT'.OR.OPFILE.EQ.'plt')IOU8 = 8
C
C     -----------------------
C     OPEN STANDARD I/O FILES
```

```
C
C       IOU5 = STD. INPUT
C       IOU6 = STD. OUTPUT
C     -------------------------
C
      IF(IOU5.EQ.5) OPEN(IOU5,FILE=IPFILE,STATUS='OLD')
      IF(IOU6.EQ.6) OPEN(IOU6,FILE=OPFILE,STATUS='NEW')
C
C     ----------------------------------
C     HOME CURSOR AND CLEAR THE DISPLAY
C     ----------------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE IPVEL(H,UN,RADIUS,UMB,XIP,YSEP,WSPD,DELZ,
     1                 ZMAX,DXO,BDLAYM)
C
C     ***********************************************************
C     SUBROUTINE IPVEL GENERATES THE VELOCITY PROFILE V(X,Z) AT
C     XVZ ALONG THE INTERACTION PLANE FOR THE TWO ROTOR CASE
C     ***********************************************************
C
      CHARACTER*1 TEMCHAR
      CHARACTER*1 ICONT(5)
      CHARACTER*1 KEY,KKEY
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      DIMENSION ZZ(60),VHMF(60),VHMK(60),VHPF(60),VHPK(60),
     1          QHM(60),QHP(60),VVMF(60),VVMK(60),VVPF(60),
     2          VVPK(60),QVM(60),QVP(60)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     ***********************************************************
C
C     -----------------------------------------------------------
C     TF IS THE INTERACTION PLANE AMPLIFICATION FACTOR
C     (ORIGINALLY DEVELOPED BY M. GEORGE IN USAAVLABS TR 68-52)
C
C     ORIGINAL EQUATION FOR TF FACTOR WAS:
C
C       TF = 1.55 - 0.55*EXP(-1.35*XIP)
C
C     REPLACED WITH MODIFIED EXPRESSION (SEE BELOW) DURING
C     CORRELATION EFFORT OF MAY 1992 FOR VERSION 2.1
C     -----------------------------------------------------------
C
      TF = 1.65 - 0.65*EXP(-0.5*XIP)
C
C     -----------------------------------------------------------
C     OBTAIN PARAMETERS AT BASE RADIUS FOR THE 'BOUNDARY LAYER'
C     -----------------------------------------------------------
C
      RIP0 = SQRT(XIP**2 + YSEP**2)
C
C     ---------------------------------------------------
C     'PROPRM' PROVIDES THE VELOCITY PROFILE PARAMETERS
C     OF A RADIAL WALL JET (WITHOUT INTERACTION PLANE)
C     ---------------------------------------------------
C
      CALL PROPRM(H,UMB,RIP0)
C
      ZIPB = ZB
      ZIPM = ZM
      ZIPH = ZH
C
      RIPM = SQRT(XIP**2 + (YSEP + ZIPM)**2)
C
      CALL PROPRM(H,UMB,RIPM)
C
```

```
      UMM = UM
C
C     ----------------------------------------------
C     INCREMENT AND MAXIMUM HEIGHT ARE DELZ AND ZMAX
C     ----------------------------------------------
C
      NPTS = IFIX(ZMAX/DELZ) + 2
C
      IF(NPTS.GT.60) NPTS = 60
C
C     ----------------------------------------
C     DIMENSIONALIZE VELOCITY PROFILE PARAMETERS
C     ----------------------------------------
C
      XXIP = RADIUS*XIP
      ZZB  = ZIPB*RADIUS
      ZZH  = ZIPH*RADIUS
      ZZM  = ZIPM*RADIUS
C
C     ---------------------------------------------------
C     OUTPUT THE VELOCITY AND DYNAMIC PRESSURE PROFILE HEADER
C     ---------------------------------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
C
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 10X,A50,/,10X,A50,//)
C
      XIPOUT = XXIP + DXO
C
      WRITE(IOU6,1000) XIPOUT
 1000 FORMAT( 2X,'TWIN ROTOR INTERACTION PLANE VELOCITY PROFILE',
     1            ' AT STATION = ',F7.1,' FT',//)
C
      WRITE(IOU6,1002)
 1002 FORMAT( 2X,'HEIGHT',8X,'MEAN VELOCITY',7X,'PEAK VELOCITY',6X,
     1       'MEAN Q',4X,'PEAK Q',/,
     2       3X,'(FT)',8X,'(FPS)',6X,'(KN)',5X,'(FPS)',6X,'(KN)',5X,
     3       '(PSF)',5X,'(PSF)',/)
C
      LINES = 0
C
C     --------------------------
C     'AN' IS ACTUALLY '= 1.0/7.0'
C     --------------------------
C
      AN = 0.142857142
C
C     ---------------------------------------------
C     CALCULATE THE VELOCITY PROFILE POINTS FOR OUTPUT
C     'NPTS' IS THE NUMBER OF VERTICAL STATION POINTS
C     ---------------------------------------------
C
      DO 500 I = 1,NPTS
C
        LINES = LINES + 2
        ZIP   = DELZ*FLOAT(I - 1)
C
C       ------------------------------------------
C       GET MAX WALL JET VELOCITY AT EFFECTIVE RADIUS
```

```
C         ----------------------------------------------
C
          RIP = SQRT(XIP**2 + (YSEP + ZIP)**2)
C
          CALL PROPRM(H,UMB,RIP)
C
          VN = UN
          VZ = UM
C
C         ---------------------------------------------
C         INTERACTION PLANE 'BOUNDARY LAYER'
C
C         CODE MODIFIED IN MAY 1992 FOR USER SPECIFIED
C         MINIMUM BOUNDARY LAYER THICKNESS (BDLAYM)
C         ---------------------------------------------
C
          ZIP1 = BDLAYM
C
          IF(ZIP.LT.ZIPM.OR.ZIP.LT.ZIP1)THEN
C
            IF(ZIP1.LT.ZIPM)THEN
C
              VZ = UMM*(ZIP/ZIPM)**AN
C
            ELSE
C
              VZ = UMM*(ZIP/ZIP1)**AN
C
            ENDIF
C
          ENDIF
C
C         ----------------------------------------------------------
C         DEVELOPED INTERACTION PLANE JET
C         CONTAINS BOTH HORIZONTAL AND VERTICAL VELOCITY COMPONENTS
C         ----------------------------------------------------------
C
          VH = TF*VZ*XIP/RIP
          VV = TF*VZ*(YSEP + ZIP)/RIP
C
          ZZ(I) = ZIP*RADIUS
C
C         ----------------------------------------
C         MEAN VELOCITIES (BOTH FT/SEC AND KNOTS)
C         ----------------------------------------
C
          VHMF(I) = VH*UN
          VVMF(I) = VV*UN
          VHMK(I) = VHMF(I)/FPSPKN
          VVMK(I) = VVMF(I)/FPSPKN
C
C         ----------------------------------------
C         PEAK VELOCITIES (BOTH FT/SEC AND KNOTS)
C
C         EQUATION FOR VMFD3I UPDATED FROM 1st TO
C         2nd ORDER POLYNOMIAL FOR VERSION 2.1
C         ----------------------------------------
C
          VMFD3I = 0.712887 + 0.304369*XIP - 0.018496*XIP*XIP
C
          IF(VMFD3I.LT.1.2) VMFD3I = 1.2
C
          VHPF(I) = VMFD3I*VHMF(I)
```

```
          VVPF(I) = VMFD3I*VVMF(I)
          VHPK(I) = VHPF(I)/FPSPKN
          VVPK(I) = VVPF(I)/FPSPKN
C
          IF(VHMF(I).EQ.0.)GOTO 55
C
C         ---------------------------------------------------------
C         THE EFFECT OF WIND IS TO ADD (DOWNWIND SIDE) OR SUBTRACT
C         (UPWIND SIDE) 'XWK' TIMES THE AMBIENT WIND VELOCITY TO
C         THE HORIZONTAL PROFILE VELOCITY (EMPIRICAL, CH-53E BASED)
C         ---------------------------------------------------------
C
          XKW = (-0.5*H) + 2.5
C
          IF(XKW.LT.1.0) XKW = 1.0
C
          WSPD2     = WSPD*XKW
          VHMK(I)   = VHMK(I) + WSPD2
          VHMF(I)   = VHMK(I)*FPSPKN
          VHPK(I)   = VHPK(I) + WSPD2
          VHPF(I)   = VHPK(I)*FPSPKN
C
   55     CONTINUE
C
C         -----------------
C         DYNAMIC PRESSURES
C         -----------------
C
          QHM(I) = RHOD2*VHMF(I)**2
          QVM(I) = RHOD2*VVMF(I)**2
          QHP(I) = RHOD2*VHPF(I)**2
          QVP(I) = RHOD2*VVPF(I)**2
C
          IF(IOU6.EQ.IOU1)THEN
C
            IF(LINES.LT.12)GOTO 450
            LINES = 2
            CALL INKEY
            IF(KEY.NE.'C')GOTO 999
            WRITE(IOU6,1002)
C
          ENDIF
C
  450     CONTINUE
C
C         ---------------------------------------------
C         REPORT HORIZONTAL COMPONENTS OF VELOCITY PROFILE
C         ---------------------------------------------
C
          WRITE(IOU6,1003) ZZ(I),VHMF(I),VHMK(I),VHPF(I),
     *                     VHPK(I),QHM(I),QHP(I)
 1003     FORMAT ( F8.2,2X,'H',6F10.3)
C
C         -------------------------------------------
C         REPORT VERTICAL COMPONENTS OF VELOCITY PROFILE
C         -------------------------------------------
C
          WRITE(IOU6,1004) VVMF(I),VVMK(I),VVPF(I),VVPK(I),
     *                     QVM(I),QVP(I)
 1004     FORMAT ( 10X,'V',6F10.3)
C
  500 CONTINUE
C
```

```
C     -----------------------------------------------------
C     WRITE OUT GRAPHICS FILES IF SWITCH IS SET BY USER
C     -----------------------------------------------------
C
      IF(IGRAPH.EQ.1)THEN
C
C        -------------------
C        OPEN GRAPHICS FILE
C        -------------------
C
         OPEN(IOU8,FILE=PTSFIL(2),STATUS='NEW',ERR=2000)
C
         WRITE(IOU8,89) COMM(1),COMM(2)
   89    FORMAT( 10X,A50,/,10X,A50,//)
C
         WRITE(IOU8,80) XIPOUT
   80    FORMAT( 1X,'TITLE="VELOCITY PROFILE, DAIP =',F5.1,' FT,'
     *               ' GW = xxxxx LB, WAGL = xx.x FT"')
C
C        -------------------------------------------------------
C        PRINT OUT MEAN VELOCITY, PEAK VELOCITY, AND PEAK
C        DYNAMIC PRESSURE PROFILES VERSUS PROFILE HEIGHT (AGL)
C        -------------------------------------------------------
C
         WRITE(IOU8,88)
   88    FORMAT( 1X,'VARIABLES = X,HT')
C
         WRITE(IOU8,81)
   81    FORMAT( 1X,'ZONE T = "MEAN PROFILE, KTS", I=xx, F=POINT')
         DO 82 I = 1,NPTS
         WRITE(IOU8,83) VHMK(I),ZZ(I)
   83    FORMAT( 1X,F6.1,1X,F6.2)
   82    CONTINUE
C
         WRITE(IOU8,84)
   84    FORMAT( 1X,'ZONE T = "PEAK PROFILE, KTS", I=xx, F=POINT')
         DO 85 I = 1,NPTS
         WRITE(IOU8,83) VHPK(I),ZZ(I)
   85    CONTINUE
C
         WRITE(IOU8,86)
   86    FORMAT( 1X,'ZONE T = "PEAK Q, PSF", I=xx, F=POINT')
         DO 87 I = 1,NPTS
         WRITE(IOU8,83) QHP(I),ZZ(I)
   87    CONTINUE
C
C        -------------------
C        CLOSE GRAPHICS FILE
C        -------------------
C
         CLOSE(IOU8,STATUS='KEEP')
C
      ENDIF
C
      CALL INKEY
C
      GOTO 999
C
C     ---------------------------------------------------
C     THE ERROR LOGIC ALLOWS FOR THE HANDLING OF FILE
C     OPEN ERRORS BY RETURNING THE USER TO A MENU
C     ---------------------------------------------------
C
```

```
 2000 CONTINUE
C
      CALL HOMCLS(0)
C
      WRITE(IOU1,2001)
 2001 FORMAT( ////,8X,
     1        ' *** ERROR ***  PLEASE CHOOSE A NEW OUTPUT FILENAME',
     2  //,8X,'               TYPE <RETURN> TO CONTINUE  ',$)
C
      READ(IOU1,'(A1)') TEMCHAR
C
      KEY = 'P'
C
  999 CONTINUE
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE IREAD(IOU1,PROMPT,IVALUE)
C
C     ***********************************************
C     SUBROUTINE IREAD PROMPTS USER FOR AN INTEGER
C     DATA ENTRY AND CHECKS VALIDITY OF ENTRY
C     ***********************************************
C
      PARAMETER(LAST=50)
C
      CHARACTER*50 PROMPT,SHOWIT
      CHARACTER*15 ENTRY,BLANK
C
      DATA BLANK /'               '/
C
C     ***********************************************
C
C     -----------------------------------------------
C     PROMPT USER FOR INTEGER ENTRY.  FIND POSITION
C     OF LAST NON-BLANK CHARACTER IN PROMPT,
C     THEN STORE RIGHT JUSTIFIED IN SHOWIT
C     -----------------------------------------------
C
      N = LAST + 1
C
   10 IF(N.EQ.1)GOTO 20
C
      N = N - 1
C
      IF(PROMPT(N:N).EQ.' ')GOTO 10
C
   20 JS = LAST - N
C
      WRITE(SHOWIT,'(50A1)') (' ',J=1,JS),(PROMPT(I:I),I=1,N)
C
C     ----------------------------
C     NOW ASK USER FOR DATA ENTRY
C     ----------------------------
C
   30 WRITE(IOU1,'(/,1X,A,I3)') SHOWIT,IVALUE
C
      WRITE(IOU1,'(/,8X,A,$)')
     1 ' ENTER NEW VALUE OR <RETURN> TO LEAVE AS IS    ==> '
C
      READ(IOU1,'(A)') ENTRY
C
      IF(ENTRY.EQ.BLANK)RETURN
C
      READ(ENTRY,'(BN,I7)',ERR=30) ITEMP
C
      IVALUE = ITEMP
C
      RETURN
      END
C
```

```
C
C
      FUNCTION LEGAL(CHDOL,IOU1,OKLIST,NUM)
C
C     ****************************************
C     FUNCTION LEGAL DETERMINES IF THE VALUE
C     FOR CHDOL IS A VALID INPUT.  THIS VALUE
C     IS CHECKED AGAINST THE LIST OF LEGAL
C     VALUE IN ARRAY OKLIST(NUM)
C     ****************************************
C
      CHARACTER*1 CHDOL,OKLIST(NUM)
C
C     ****************************************
C
      LEGAL = 0
C
      DO 10 I=1,NUM
      IF(CHDOL.EQ.OKLIST(I)) RETURN
   10 CONTINUE
C
      LEGAL = 1
C
      WRITE(IOU1,'(/,T9,A,A1,A/)') ' ***  ',CHDOL,
     1 ' IS NOT A VALID INPUT ***'
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE LOCATE(IROW,ICOL)
C
C     *****************************************************
C     SUBROUTINE LOCATE LOCATES THE CURSOR POSITION
C     *****************************************************
C
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
      CHARACTER*8 CUP
      CHARACTER*1 ECUP(8)
      EQUIVALENCE (CUP,ECUP(1))
C
      CHARACTER*10 FMT
      CHARACTER*1  EFMT(10)
      EQUIVALENCE (FMT,EFMT(1))
C
      DATA FMT / '(" ",A? \)' /
C
C     *****************************************************
C
C     -------------------------------------------------
C     ANSI CONTROL SEQUENCE: CUP = ESC['ROW';'COLUMN'H
C     -------------------------------------------------
C
      IR1 = IROW/10
      IR2 = IROW - IR1*10
      IC1 = ICOL/10
      IC2 = ICOL - IC1*10
C
      ECUP(1) = CHAR(27)
      ECUP(2) = CHAR(91)
      IPOS    = 3
C
      IF(IR1.GT.0)THEN
        ECUP(IPOS)  = CHAR(IR1 + 48)
        IPOS        = IPOS + 1
      ENDIF
C
      ECUP(IPOS)  = CHAR(IR2 + 48)
      IPOS        = IPOS + 1
C
      ECUP(IPOS)  = CHAR(59)
      IPOS        = IPOS + 1
C
      IF(IC1.GT.0)THEN
        ECUP(IPOS)  = CHAR(IC1 + 48)
        IPOS        = IPOS + 1
      ENDIF
C
      ECUP(IPOS)  = CHAR(IC2 + 48)
      IPOS        = IPOS + 1
C
      ECUP(IPOS)  = CHAR(72)
C
      EFMT(7) = CHAR(IPOS + 48)
C
      WRITE(IOU1,*) CUP
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE MOMENT(NPTS,HUMTYP,TOTF,TOTM)
C
C     *****************************************************
C     SUBROUTINE MOMENT CALCULATES THE TOTAL OVERTURNING
C     FORCE AND MOMENT ON A MAN OR YOUNG PERSON AND PRINTS
C     OUT THE RESULTS.
C     *****************************************************
C
CPAX      DIMENSION PAXMAN(12)
      CHARACTER*1 HUMTYP
C
      COMMON /PERSON/ QP(12),DSET
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     *****************************************************
C
C     ---------------------------------------------------------
C     IN THE SUBROUTINE TO CALCULATE FORCES AND MOMENTS:
C
C       "CDP" IS THE COEFFICIENT OF DRAG OF THE PERSON:
C         CDP = 1.1 FOR HAZARD ANALYSES
C         CDP = 1.0 FOR CORRELATION WITH NATC FLIGHT TEST DATA
C       "WIDTHP" IS THE WIDTH OF THE PERSON WHERE:
C         WIDTHP IS 'L' TYPE IF 1.1 FT
C         WIDTHP IS 'S' TYPE IF 0.7 FT
C     ---------------------------------------------------------
C
      WIDTHP = 1.1
      CDP    = 1.1
C
C     ---------------------------------------------------------
C     INITIALIZE AREAS FOR NATC MAN FROM ROTORWASH FLIGHT TESTS
C     (UNITS ARE FEET2)
C     ---------------------------------------------------------
C
CPAX      CDP    = 1.1
CPAX      PAXMAN(1)  = 0.41
CPAX      PAXMAN(2)  = 0.37
CPAX      PAXMAN(3)  = 0.365
CPAX      PAXMAN(4)  = 0.42
CPAX      PAXMAN(5)  = 0.5425
CPAX      PAXMAN(6)  = 0.685
CPAX      PAXMAN(7)  = 0.8
CPAX      PAXMAN(8)  = 0.845
CPAX      PAXMAN(9)  = 0.7875
CPAX      PAXMAN(10) = 0.625
CPAX      PAXMAN(11) = 0.3
CPAX      PAXMAN(12) = 0.00625
C
C     -------------------------------------------------------------
C     INITIALIZE INTEGRATION STEP SIZE AND ZERO SUMMATION VARIABLES
C     -------------------------------------------------------------
C
      DELZZ = 0.5
      TOTM  = 0.0
      TOTF  = 0.0
C
C     ----------------------
C     CHOOSE HUMAN SIZE TYPE
C     ----------------------
C
```

```
      IF(HUMTYP.EQ.'S')THEN
         WIDTHP = 0.7
         NPTS   = 8
      END IF
C
C     ---------------------------------------
C     INTEGRATE DYNAMIC PRESSURE PROFILE OVER
C     THE HEIGHT OF THE PERSON CHOSEN
C     ---------------------------------------
C
      DO 10 J = 1,NPTS
C
      FOVER = QP(J)*DELZZ*WIDTHP*CDP
CPAX        FOVER = QP(J)*PAXMAN(J)*CDP
      ZZ    = 0.5*(J - 1) + 0.25
      OVERM = FOVER*ZZ
      TOTF  = TOTF + FOVER
      TOTM  = TOTM + OVERM
C
C     -----------------
C     PRINT OUT RESULTS
C     -----------------
C
      IF(DSET.NE.0.)GOTO 10
C
      WRITE(IOU6,20) ZZ,QP(J),FOVER,OVERM,TOTF,TOTM
   20 FORMAT( F8.2,5(2X,F10.3))
C
   10 CONTINUE
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE PROPRM(H,UMB,RVZ)
C
C
*******************************************************************
C     SUBROUTINE PROPRM
C
C     THIS SUBROUTINE CALCULATES THE VELOCITY PROFILE V(R,Z)
PARAMETERS
C     OF THE RADIAL WALL JET FOR THE NON-INTERACTING ROTOR CASE
C
*******************************************************************
C
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
C
C
*******************************************************************
C
      IF(RVZ.GE.RJ)GOTO 600
C
C     ------------------------------------------------------
C     RVZ .LT. RJ ==> TRANSITION REGION
C
C     TRANSITION REGION EQUATIONS, EMPIRICALLY APPLIED BY
C     JDK PRIOR TO VERSION 2.1, WERE SIGNIFICANTLY IMPROVED
C     BY THE FOLLOWING CHANGES FOR V2.1 IN MAY 1992.
C
C     OLD OR REPLACED EQUATIONS:
C
C       UM = UMJ*RVZ
C       IF(RVZ.GT.1.0) UM = UMJ
C       ZH = ZHJ*RVZ
C       IF(RVZ.GT.1.0) ZH = ZHJ
C       ZM = ZMJ*RVZ
C       IF(RVZ.GT.1.0) ZM = ZMJ
C     ------------------------------------------------------
C
      UM = UMJ*(RVZ/RJ)**0.5
C
C     ----------------------------------------------
C     BOUNDARY GROWTH IN TRANSITION REGION
C
C     SEE NOTE ABOVE
C
C     OLD OR REPLACED EQUATIONS:
C
C       ZB0 = 1.5
C       IF(H.LT.1.5) ZB0 = H
C       ZH  = (ZH0 - ZHJ)/RJ**2*(RJ - RVZ)**2 + ZHJ
C     ----------------------------------------------
C
      ZB0 = H**0.5
      ZH0 = ZB0/2.5
C
      ZH  = (ZH0 - ZHJ)/RJ**2*(RJ - RVZ)**1.5 + ZHJ
      ZB  = 2.5*ZH
      ZM  = 0.33*ZH
C
      GOTO 700
C
C     ---------------------------------------------
C     RVZ .GE. RJ ==> DEVELOPED WALL JET REGION
```

```
C
C     SEVERAL COEFFICIENTS IN THE GROWTH EQUATIONS
C     WERE MODIFIED IN MAY 1992 FOLLOWING THE
C     CORRELATION EFFORT (SEE NOTES IN SUBROUTINE
C     WALJET FOR DETAILS).
C
C     OLD EQUATIONS:
C
C       UM = CU*RVZ**(-1.143)*UMB
C       ZH = CY*RVZ**(1.028)
C       ZM = 0.1944*ZH
C     ---------------------------------------------
C
  600 CONTINUE
C
      UM = CU*RVZ**(-1.0)*UMB
      ZH = CY*RVZ**(1.0)
      ZB = 2.8*ZH
      ZM = 0.28*ZH
C
  700 CONTINUE
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE VLINE
C
C
*****************************************************************
C     SUBROUTINE VLINE
C
C     THIS SUBROUTINE APPLIES THE BIOT-SAVORT LAW TO
C     CALCULATE THE VELOCITY INDUCED BY A LINE VORTEX
C
C     XA,YA,ZA = STARTING POINT OF VORTEX
C     XB,YB,ZB = ENDING POINT, OR DIRECTION POINTER
C     XC,YC,ZC = TARGET POINT WHERE VELOCITY IS INDUCED
C
C     IFI = 0      VORTEX IS FINITE, FROM POINT A TO POINT B
C     IFI = 1      VORTEX IS SEMI-INFINITE FROM POINT A THROUGH B
C
C
*****************************************************************
C
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /CVLINE/ IFI,XA,YA,ZA,XB,YB,ZB,XC,YC,ZC,Q1,Q2,Q3
C
C
*****************************************************************
C
      A  = (XA-XC)**2 + (YA-YC)**2 + (ZA-ZC)**2
      B  = 2.0*( (XA-XB)*(XC-XA) + (YA-YB)*(YC-YA) + (ZA-ZB)*(ZC-ZA)
 )
      C  = (XA-XB)**2 + (YA-YB)**2 + (ZA-ZB)**2
C
      C1 = (YC-YB)*ZA + (YA-YC)*ZB + (YB-YA)*ZC
      C2 = (ZC-ZB)*XA + (ZA-ZC)*XB + (ZB-ZA)*XC
      C3 = (XC-XB)*YA + (XA-XC)*YB + (XB-XA)*YC
C
      Q  = 4.0*A*C - B**2
C
C     -------------------------------
C     CHECK FOR COLINEAR TARGET POINT
C     -------------------------------
C
      QB = 0.0
      IF(ABS(Q).LT.1.0E-06)GOTO 100
C
C     --------------------
C     FINITE LENGTH VORTEX
C     --------------------
C
      IF(IFI.EQ.0)THEN
        QB = 1.0/Q*((2.0*C + B)/SQRT(A + B + C) - B/SQRT(A))/2.0/PI
      ENDIF
C
C     --------------------
C     SEMI-INFINITE VORTEX
C     --------------------
C
      IF(IFI.EQ.1)THEN
        QB = 1.0/Q*(2.0*SQRT(C) - B/SQRT(A))/2.0/PI
      ENDIF
C
  100 CONTINUE
C
```

```
C       --------------------
C       VELOCITY COMPONENTS
C       --------------------
C
        Q1 = C1*QB
        Q2 = C2*QB
        Q3 = C3*QB
C
        RETURN
        END
C
```

```
C
C
      SUBROUTINE WALJET(H,UB,UN,UMB)
C
C
*********************************************************************
C     SUBROUTINE WALJET
C
C     THIS SUBROUTINE CALCULATES THE STARTING POSITION OF THE
C     WALL JET AND GROWTH PARAMETERS FOR WALL JET DECAY
C
*********************************************************************
C
      COMMON /CLOUDK/ QSMAX
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C
*********************************************************************
C
C     ------------------------------------------------------------
C     INITIALIZATION OF EXPONENTS
C
C     CZM, THE PROFILE PEAK VELOCITY LOCATION, WAS INCREASED
C     FROM THE GLAUERT VALUE (0.1944) TO THE PRESENT VALUE
C     BASED ON DATA AND ASSUMPTIONS PRESENTED IN FAA REPORT
C     FOR VERSION 2.1, MAY 1992.  THE OTHER COEFFICIENTS WERE
C     MODIFIED WHEN IT WAS DEMONSTRATED THAT CORRELATION WAS
C     IMPROVED WITH BOTH MODEL AND FLIGHT TEST DATA.
C
C     VARIABLE      VALUE FOR V2.1    BEFORE V2.1
C
C       EXU              -1.0            -1.143
C       EXY               1.0             1.028
C       CZM               0.28            0.1944
C       QSMAX0            1.077           1.0     (SEE NOTE BELOW)
C     ------------------------------------------------------------
C
      EXU = -1.0
      EXY =  1.0
      EXM =  1.0 + EXU + EXY
      CZM =  0.28
      CZB =  2.8
C
C     ---------------------------------------------
C     ITERATE TO FIND INITIAL RADIUS OF WALL JET, RJ
C     ---------------------------------------------
C
      TOL = 1.0E-05
      RJ  = 2.0
C
      QSMAX0 = 1.077
C
      DO 100 I=1,20
C
C     -------------------------------------
C     CALCULATION OF EQUIVALENT JET LENGTH
C     -------------------------------------
C
      TR  = H + (RJ - 1.0)
      TDE = 0.707*TR
C
C     -------------------------------------------------------------
```

```
C     QSMAX CURVEFIT ORIGINALLY TO FIG. 8, USAAVLABS TECHNICAL
C     REPORT 68-52, JULY 1968.  UPDATED INFORMATION FROM FIG. 2,
C     REPORT DTNSRDC/ASED-79/04, APRIL 1979.
C
C     OLD TR 68-52 EQUATIONS:
C
C       QSMAX0 = 1.0
C       IF(TDE.LE.4.0) QSMAX = QSMAX0 + (0.6 - QSMAX0)/16.0*TDE**2
C       IF(TDE.GT.4.0) QSMAX = 2.4/TDE
C
C     RJNEW COEFFICIENTS ROUNDED OFF DURING MAY 1992 CORRELATION
C     EFFORT WHICH PRODUCED IMPROVED RESULTS WHEN SIMPLIFICATIONS
C     WERE INTRODUCED
C
C     OLD EQUATION:
C
C       RJNEW = 2.508078*(UB/UM)**(0.486)
C     ------------------------------------------------------------
C
      IF(TDE.LE.3.5) QSMAX = 1.08 - 0.025*TDE**2
      IF(TDE.GT.3.5) QSMAX = 2.7/TDE
C
      UM  = SQRT(QSMAX)
C
      RJNEW = 2.5*(UB/UM)**(0.5)
C
      IF(ABS(RJNEW - RJ).LE.TOL)GOTO 200
      RJ = RJNEW
C
  100 CONTINUE
C
      WRITE(IOU1,10)
   10 FORMAT( '************************************************',/
     1       ,'ITERATIONS EXCEEDED FOR WALL JET INITIAL RADIUS',/
     2       ,'************************************************')
C
      STOP ' '
C
  200 CONTINUE
C
      RJ = RJNEW
C
C     --------------------------------------------------------------
C     VELOCITY GROWTH FUNCTION CONSTANTS
C
C     TWO CONSTANTS WERE ROUNDED OFF TO SIMPLIFY THE FOLLOWING
C     TWO EQUATIONS DURING THE CORRELATION EFFORT OF MAY 1992
C     FOR VERSION 2.1
C
C     OLD EQUATIONS:
C
C       UMB = ((0.3586*RJ**EXM*(UM*UN)*(UB*UN)**(0.14))**(0.88))/UN
C       ZHJ = 0.654/(UM/UMB)**2/RJ
C     --------------------------------------------------------------
C
      UMB = ((0.36*RJ**EXM*(UM*UN)*(UB*UN)**(0.14))**(0.88))/UN
      ZHJ = 0.65/(UM/UMB)**2/RJ
      CU  = UM/UMB*RJ**(-EXU)
      CY  = ZHJ*RJ**(-EXY)
C
C     ---------------------------------------
C     MAX VELOCITY AND BOUNDARY PARAMETERS AT RJ
C     ---------------------------------------
```

```
C
      UMJ = CU*RJ**(EXU)*UMB
      ZHJ = CY*RJ**(EXY)
      ZMJ = CZM*ZHJ
      ZBJ = CZB*ZHJ
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE WJVEL(H,UN,UMB,RVZ,RADIUS,WSPD,DELZ,ZMAX,DXO,BDLAYM)
C
C     **************************************************
C     SUBROUTINE WJVEL GENERATES THE VELOCITY PROFILE V(R,Z)
C     AT RVZ FOR THE NON-INTERACTING ROTOR CASE
C     **************************************************
C
      CHARACTER*1  TEMCHAR
      CHARACTER*1  ICONT(5)
      CHARACTER*1  KEY,KKEY
      CHARACTER*12 PTSFIL(4)
      CHARACTER*50 COMM(2)
C
      DIMENSION ZZ(60),VMF(60),VMK(60),VPF(60),
     1           VPK(60),QM(60),QP(60)
C
      COMMON /  CKEY/ KEY,KKEY
      COMMON /CONSTS/ PI,RHO,FPSPKN,RHOD2,DRC
      COMMON /INPUTC/ ICONT,COMM,PTSFIL
      COMMON /PROFIL/ RJ,ZBJ,ZHJ,ZMJ,UMJ,ZB,ZH,ZM,UM,CU,CY
      COMMON / UNITS/ IOU1,IOU4,IOU5,IOU6,IOU7,IOU8,IGRAPH
C
C     **************************************************
C
C     -----------------------------------------------
C     'PROPRM' PROVIDES THE VELOCITY PROFILE PARAMETERS
C     OF A RADIAL WALL JET (WITHOUT INTERACTION PLANE)
C     -----------------------------------------------
C
      CALL PROPRM(H,UMB,RVZ)
C
C     -----------------------------------------
C     DIMENSIONALIZE VELOCITY PROFILE PARAMETERS
C     -----------------------------------------
C
      RRVZ   = RADIUS*RVZ
      ZZB    = ZB*RADIUS
      ZZH    = ZH*RADIUS
      ZZM    = ZM*RADIUS
C
      ZETAH = ZH/ZB
      ZETAM = ZM/ZB
C
C     ---------------------------------------------------
C     OUTPUT THE VELOCITY AND DYNAMIC PRESSURE PROFILE HEADER
C     ---------------------------------------------------
C
      ICD = 0
      CALL HOMCLS(ICD)
      IF(IOU6.NE.IOU1) WRITE(IOU6,'(''1'')')
C
      IF(IOU6.EQ.6) WRITE(IOU6,93) COMM(1),COMM(2)
   93 FORMAT( 10X,A50,/,10X,A50,//)
C
      RVZOUT = RRVZ + DXO
C
      WRITE(IOU6,1000) RVZOUT
 1000 FORMAT( 9X,'SINGLE ROTOR VELOCITY PROFILE AT RADIUS = ',
     1   F7.1,' FT',/)
C
      WRITE(IOU6,1001) ZZB,ZZH,ZZM
```

```
 1001 FORMAT( 15X,'PROFILE BOUNDARY HEIGHT = ',F7.2,' FT',/
     1       ,15X,'        HALF-VEL.HEIGHT = ',F7.2,' FT',/
     2       ,15X,'        MAX-VEL  HEIGHT = ',F7.2,' FT',/)
C
C     ---------------------------------------------
C     INCREMENTS AND HEIGHT ARE FROM DELZ AND ZMAX
C     ---------------------------------------------
C
      NPTS = IFIX(ZMAX/DELZ) + 1
C
C     ----------------------------
C     BOUNDARY LAYER REGION EXPONENT
C     'AN' IS ACTUALLY = 1.0/7.0
C     ----------------------------
C
      AN = 0.142857142
C
C     -------------------------------------------------------------
C     SHEAR LAYER REGION EXPONENT, TO MEET EDGE CONDITIONS
C     (FROM FIGURE 7, USAAVLABS TECHNICAL REPORT 68-52, JULY 1968)
C     -------------------------------------------------------------
C
      ALPW = ALOG(1.0 - 1.0/SQRT(2.0))/ALOG((ZH - ZM)/(ZB - ZM))
C
      VN  = UN
      VMN = UM
C
C     --------------------------------------------------------
C     CALCULATION OF THE NON-DIMENSIONALIZED MINIMUM ALLOWED
C     BOUNDARY LAYER THICKNESS SO THAT THE BOUNDARY LAYER CAN
C     BE ADJUSTED IF THE ZM POSITION IS PHYSICALLY TOO LOW
C     (BDLAYM, IN FEET, COMES FROM A MENU INPUT PARAMETER)
C     --------------------------------------------------------
C
      ZETA1 = BDLAYM/ZB
C
C     --------------------------------------------------------
C     OUTPUT THE VELOCITY AND DYNAMIC PRESSURE PROFILE HEADER
C     --------------------------------------------------------
C
      WRITE(IOU6,1005)
 1005 FORMAT( 2X,'HEIGHT',5X,'MEAN VELOCITY',7X,'PEAK VELOCITY',6X,
     1       'MEAN Q',4X,'PEAK Q',/,
     2       3X,'(FT)',5X,'(FPS)',6X,'(KN)',5X,'(FPS)',6X,'(KN)',5X,
     3       '(PSF)',5X,'(PSF)',/)
C
C     -------------------------------------------------
C     CALCULATE THE VELOCITY PROFILE POINTS FOR OUTPUT
C     -------------------------------------------------
C
      LINES = 0
C
      DO 500 I = 1,NPTS
C
        LINES = LINES + 1
        Z     = DELZ*FLOAT(I - 1)
        ZETA  = Z/ZB
C
        IF(ZETA.LT.ZETAM.OR.ZETA.LT.ZETA1)THEN
C
C         ------------------------------------------------
C         Z IS WITHIN BOUNDARY LAYER
C
```

```
C          NOTE THAT THE BOUNDARY LAYER CALCULATIONS NOW USE
C          THE MINIMUM THICKNESS PARAMETER AND THE PEAK TO
C          MEAN VELOCITY PARAMETER IS THE MAXIMUM VELOCITY
C          HEIGHT RATIO (AT ZM).   ADDED MAY 1992 FOR V2.1.
C          ----------------------------------------------
C
           VZM = 0.0
C
           IF(ZETAM.GT.0.0)THEN
C
             VZM = (ZETA/ZETAM)**AN
C
             IF(ZETA1.GT.ZETAM)THEN
C
               VZM1 = (1.0 - ((ZETA1 - ZETAM)/(1.0 - ZETAM))**ALPW)**2
               VZM  = VZM1*(ZETA/ZETA1)**AN
C
             ENDIF
C
             VMTOPK = 1.04653 + 0.373894*RVZ - 0.0422525*RVZ*RVZ
C
             IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
           ENDIF
C
           GOTO 400
C
         ENDIF
C
C        ----------------------------------------------
C        Z IS WITHIN SHEAR LAYER
C
C        THE PEAK TO MEAN VELOCITY RATIO EQUATIONS ARE
C        SUBSTANTIALLY IMPROVED OVER THOSE USED PRIOR TO
C        MAY 1992.  EQUATIONS ARE NOW USED FOR BOTH THE
C        MAXIMUM VELOCITY HEIGHT (ZM) AND THE 1/2 VELOCITY
C        HEIGHT (ZH).  VALUES BETWEEN ARE INTERPOLATED AND
C        VALUES ABOVE ZH USE THE ZH RATIO*(ZETA/ZETAH).
C        THESE 2nd ORDER EQUATION SUBSTANTIALLY IMPROVED
C        CORRELATION WITH MODEL AND FLIGHT TEST DATA
C        DURING THE MAY 1992 EFFORT FOR V2.1.
C        ----------------------------------------------
C
         VZM = 0.0
C
         IF(Z.LE.ZB)THEN
C
           VZM = (1.0 - ((ZETA - ZETAM)/(1.0 - ZETAM))**ALPW)**2
C
           IF(ZETA.GE.ZETAH)THEN
C
             VMTOPK = (1.48086 + 0.569177*RVZ - 0.0692514*RVZ*RVZ)
     1                *(ZETA/ZETAH)
C
             IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
           ELSE
C
             VMPKMX = 1.04653 + 0.373894*RVZ - 0.0422525*RVZ*RVZ
C
             VMPK12 = 1.48086 + 0.569177*RVZ - 0.0692514*RVZ*RVZ
C
             FRAC   = (ZETA - ZETAM)/(ZETAH - ZETAM)
```

```
C
            IF(ZETA1.GT.ZETAM)THEN
C
              FRAC    = (ZETA - ZETA1)/(ZETAH - ZETA1)
C
            ENDIF
C
            VMTOPK = FRAC*VMPK12 + (1.0 - FRAC)*VMPKMX
C
            IF(VMTOPK.LT.1.2) VMTOPK = 1.2
C
          ENDIF
C
        ENDIF
C
  400   CONTINUE
C
        VZN = VZM*VMN
C
C       ------------------
C       DIMENSIONAL HEIGHT
C       ------------------
C
        ZZ(I) = Z*RADIUS
C
C       ---------------
C       MEAN VELOCITIES
C       ---------------
C
        VMF(I) = VZN*VN
        VMK(I) = VMF(I)/FPSPKN
C
C       ---------------
C       PEAK VELOCITIES
C       ---------------
C
        VPF(I) = VMF(I)*VMTOPK
        VPK(I) = VPF(I)/FPSPKN
C
        IF(VPK(I).EQ.0.0)GOTO 55
C
C       -----------------------------------------------------------
C       THE EFFECT OF WIND IS TO ADD (DOWNWIND SIDE) OR SUBTRACT
C       (UPWIND SIDE) 'XWK' TIMES THE AMBIENT WIND VELOCITY TO
C       THE HORIZONTAL PROFILE VELOCITY (EMPIRICAL, CH-53E BASED)
C       -----------------------------------------------------------
C
        XKW    = (-0.5*H) + 2.5
C
        IF(XKW.LT.1.0) XKW = 1.0
C
        WSPD2   = WSPD*XKW
        VMK(I) = VMK(I) + WSPD2
        VMF(I) = VMK(I)*FPSPKN
        VPK(I) = VPK(I) + WSPD2
        VPF(I) = VPK(I)*FPSPKN
C
   55   CONTINUE
C
C       ----------------
C       DYNAMIC PRESSURE
C       ----------------
C
```

```
            QM(I) = RHOD2*VMF(I)**2
            QP(I) = RHOD2*VPF(I)**2
C
            IF(IOU6.EQ.IOU1)THEN
              IF(LINES.LT.12)GOTO 450
              LINES = 1
              CALL INKEY
              IF(KEY.NE.'C')GOTO 999
              WRITE(IOU6,1005)
            ENDIF
C
    450     CONTINUE
C
C           ---------------------------------------------------
C           OUTPUT THE VELOCITY AND DYNAMIC PRESSURE PROFILES
C           ---------------------------------------------------
C
            WRITE(IOU6,1002) ZZ(I),VMF(I),VMK(I),VPF(I),
     *                       VPK(I),QM(I),QP(I)
   1002     FORMAT( F8.2,6F10.3)
C
    500 CONTINUE
C
C         ---------------------------------------------------
C         WRITE OUT GRAPHICS FILES IF SWITCH IS SET BY USER
C         ---------------------------------------------------
C
          IF(IGRAPH.EQ.1)THEN
C
C           -------------------
C           OPEN GRAPHICS FILE
C           -------------------
C
            OPEN(IOU8,FILE=PTSFIL(1),STATUS='NEW',ERR=2000)
C
            WRITE(IOU8,89) COMM(1),COMM(2)
     89     FORMAT( 10X,A50,/,10X,A50,//)
C
            WRITE(IOU8,80) RVZOUT
     80     FORMAT( 1X,'TITLE="VELOCITY PROFILE, DFRC =',F5.1,' FT,'
     *                 ' GW = xxxxx LB, WAGL = xx.x FT"')
C
C           ------------------------------------------------------
C           PRINT OUT MEAN VELOCITY, PEAK VELOCITY, AND PEAK
C           DYNAMIC PRESSURE PROFILES VERSUS PROFILE HEIGHT (AGL)
C           ------------------------------------------------------
C
            WRITE(IOU8,88)
     88     FORMAT( 1X,'VARIABLES = X,HT')
C
            WRITE(IOU8,81)
     81     FORMAT( 1X,'ZONE T = "MEAN PROFILE, KTS", I=xx, F=POINT')
C
            DO 82 I = 1,NPTS
            WRITE(IOU8,83) VMK(I),ZZ(I)
     83     FORMAT( 1X,F6.1,1X,F6.2)
     82     CONTINUE
C
            WRITE(IOU8,84)
     84     FORMAT( 1X,'ZONE T = "PEAK PROFILE, KTS", I=xx, F=POINT')
C
            DO 85 I = 1,NPTS
            WRITE(IOU8,83) VPK(I),ZZ(I)
```

```
      85   CONTINUE
C
           WRITE(IOU8,86)
      86   FORMAT( 1X,'ZONE T = "PEAK Q, PSF", I=xx, F=POINT')
C
           DO 87 I = 1,NPTS
           WRITE(IOU8,83) QP(I),ZZ(I)
      87   CONTINUE
C
C          -------------------
C          CLOSE GRAPHICS FILE
C          -------------------
C
           CLOSE(IOU8,STATUS='KEEP')
C
        ENDIF
C
        CALL INKEY
C
        GOTO 999
C
C       ---------------------------------------------
C       THE ERROR LOGIC ALLOWS FOR THE HANDLING OF FILE
C       OPEN ERRORS BY RETURNING THE USER TO A MENU
C       ---------------------------------------------
C
    2000 CONTINUE
C
        CALL HOMCLS(0)
        WRITE(IOU1,2001)
    2001 FORMAT( ////,8X,
       1         ' *** ERROR ***  PLEASE CHOOSE A NEW OUTPUT FILENAME'
       2  //,8X,'               TYPE <RETURN> TO CONTINUE  ',$)
        READ(IOU1,'(A1)') TEMCHAR
        KEY = 'P'
C
     999 CONTINUE
C
        RETURN
        END
C
```


END